UNIVERSITY OF PENNSYLVANIA

AN ANALYSIS OF CERTAIN OUTCOMES IN THE TEACHING OF PHYSICS IN PUBLIC HIGH SCHOOLS

WITH

AN INVESTIGATION OF THE EFFICIENCY OF A LABORATORY METHOD IN ESTABLISHING SUCH OUTCOMES

JOHN H. DYER

A THESIS

IN EDUCATION

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

PHILADELPHIA

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To my Mother

Whose Fidelity is an Inspiration

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I

Introductory: Purpose and Method

It is the purpose of this thesis to assemble possible educational objectives from the teaching of physics in public high schools; to select from them a few which not only are frequently recurring among objectives accepted as valid by specialists in the subject but which also may receive a unique contribution from physics and which have a high range and recurrence of usefulness; to construct for each objective selected the complex of mental characteristics essential for making the objective a useful reality; and to exemplify the sort of experimentation by which must eventually be determined the most efficient methods of establishing those mental characteristics. It is not the purpose of the thesis to assemble *all* possible educational objectives in the teaching of physics or to prove that those selected for analysis with a view to their control of conduct are the most useful objectives. That they are among the most useful, however, is proved both by their recurrence among objectives generally accepted by writers on the teaching of physics and by their range and recurrence of usefulness in ordinary experience so high and so apparent that there is no question of a doubt of their usefulness. They also stand out from other possible outcomes through the fact that from physics they may receive a uniquely potent contribution and that in this sense they may be regarded as "unique" objectives in the teaching of physics.

When the writer first undertook this study about three years ago, he was motivated by a desire to organize his own work in the teaching of physics. For such an undertaking, current general aims in education are little more than useless: and analysis in terms of conduct control is nowhere to be found. This lack of an analysis of outcomes valid for the teaching of physics in public high schools is precisely what the writer has in the first part of his book attempted to remove. How successfully the analysis has been made can be determined only by experimentation performed in as refined scientific fashion as present-day exactness in educational measurements would seem

to warrant. A legion of controlled experiments will be needed: experiments to test the adequacy of controlling power of certain mental characteristics; experiments to test the number of contributing factors necessary for establishing a certain mental characteristic; experiments involving relative efficiency in methods of establishing mental characteristics. An attempt has been made in the second part of the work to exemplify one of the many kinds of experimentation which must go hand-in-hand with the analysis found in Chapter 5.

The effectiveness of educational practice depends upon the soundness of the psychology and the philosophy back of the practice. If the psychology or the philosophy of education is at fault, practice will inevitably suffer in desirable results attained. The second chapter is entitled "Education as Conduct Control" and defines the conception of the function of education upon which the whole treatise must stand or fall. Throughout the discussion the word conduct is employed to connote thought and feeling as well as overt action. The presentation is an epitome of a system worked out in detail by Dr. A. Duncan Yocum of the University of Pennsylvania in his "Analysis of Education as Conduct Control."

Physics teaching in a public high school must find its *raison d'être* in its contribution toward developing "in each individual the knowledge, interests, ideals, habits, and powers whereby he will find his place and use that place to shape both himself and society toward ever nobler ends."[1] As long, however, as the purpose of physics teaching is couched in such general terms, little progress can be made in organization of subject matter for efficiency in instruction. Chapter 2 is an exposition of the analysis upon which the detailed application to physics, found later in the book, has been based. It is only with an understanding of this analysis, and when education is considered as conduct control, that the application itself becomes meaningful.

It will be necessary, for instance, from the outset to know

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[1] *The Cardinal Principles of Secondary Education.* U. S. Bureau of Education, Bulletin No. 35, 1918, p. 9.

that the contributions of education to the control of conduct depend upon the form in which knowledge or experience is retained. Much of the knowledge or experience which comes to us very soon becomes forgotten knowledge or experience. The effect upon the mind, however, of this form of retention, "forgotten knowledge or experience" is of tremendous importance, for out of forgotten knowledge and experiences are built "impressions", a form of control which may control conduct. Pupils will quickly forget the exact value of a calory, but knowledge of calories even though forgotten may have strengthened the impression that food should be selected wisely. No one will gainsay that such an impression does affect conduct. In Chapter 2 other "forms of retention" with their corresponding "forms of control" are outlined and discussed.

It will be necessary also to understand from the beginning that the *forms* of control are rigorously analyzed into *elements* depending for their existence upon the distinguishing suggestiveness and distinguishing method of the control form in question. Each form of control has a peculiar *suggestiveness* for experience from the point of view of the *way* in which control is exercised and a peculiar *method* of developing the control. "Impression control", for example, has as its distinguishing suggestiveness an abiding potent sensation or *feeling*. When "impressions" control conduct, they control by reason of this *feeling*. The method of developing impression control is, consequently, the method of developing a feeling: cumulative instruction and cumulative experience. The method of assuring the control is called the *distinguishing method:* the way in which it acts is called its *distinguishing suggestiveness*. The distinguishing method of Impression Control is therefore "cumulative instruction": the distinguishing suggestiveness is, by the same token, "a permanent feeling strong enough to be controlling."

There are, moreover, different and more or less well defined classes of feelings. There is the feeling of familiarity with the consciousness that one has previously experienced the event, there is the accustomed feeling without conscious reason, there is the well centered feeling about something or toward something, etc., etc. Each one of these classes of feelings is the justification

for a control element under the more general "impression control" form. The first kind of feeling, the feeling of familiarity with the consciousness that one has previously experienced the event, gives rise to "realizations" as a control element. The *distinguishing suggestiveness* of this control element is the feeling of familiarity: the distinguishing method is the method best adapted to building up such a feeling; that is, selected accessory realizations and the employing of immediate, revived, or assembled experiences to establish the feeling.

Chapter 3 deals with the selection of valid objectives in the teaching of physics which when interpreted in terms of mental characteristics furnish the basis for the seven outcomes analyzed in Chapter 5. Throughout the thesis a distinction between an "objective" and an "outcome" has been recognized. An objective in the teaching of physics is a result of the teaching expressed in terms of action either mental or physical: an outcome in the teaching of physics is a subjective result expressed in terms of mental characteristics, the condition of mind which will ensure the desired objective. Objective is the more common term: outcome denotes more specifically the kind of result aimed at when education is thought of in terms of conduct control. For use in the work to follow, "objectives" and "purposes" are synonymous.

The validity of objectives depends upon their range and recurrence and emotional appeal as manifested in accepted purposes, social demand and need, and by scientific determination. In Chapter 3 will be found an investigation of the range and recurrence of prevalent objectives as revealed by the examination of thirty-five professional treatises on objectives in the teaching of science. The objectives most frequently occurring in the professional articles reviewed are the objectives that have been selected for analysis. Considerations of the other avenues of approach—namely, social demand and need and scientific determination—further sanction their selection. Range and recurrence and emotional appeal in social demand and need and in scientific determination measure relative worth or usefulness of education outcomes. It must be recognized, however, that an outcome may have unique value: in such an instance, relative

worth need not be determined,—the outcome is a minimum essential regardless of its range or recurrence or emotional appeal. The significance to human welfare of the outcomes analyzed is discussed in Chapter 3.

Chapter 4 explains the nature of an "instruction complex". It is here that one finds the reason for the inclusion of each element under the several outcomes. All of that organization which insures the outcome in question is called a complex. Every complex is made up of elements determined not in a subjective fashion by the crotchet or caprice of the writer but by the *distinguishing method* (established by experimentation) for the building up of the kind of outcome in question. To be specific in just one instance—the complex, a realization of the relation of physics to commerce and industry, must be built up in a very definite way. Because it is a realization, its *distinguishing method* (as determined by experimentation) calls for presentation of selected realizations, either immediate, revived, or assembled.[2] Moreover there must be enough of them to make the realization controlling. There must be strengthening and counteracting elements, completing and limiting elements, interconnecting and transfer elements. In other words a very definite criterion (the requisites of the *distinguishing method* for each control form) operates for the inclusion or exclusion of all possible elements. There is no room for vacillation. When once the nature of the outcome has been decided upon, the elements of the complex are determined by the distinguishing method. Only experimentation can determine which or how many are required, but there must be enough of them developed to make the outcome real.

Chapter 5 contains the analysis of the seven major outcomes. The complexes necessary to a realization of these outcomes have been intensively treated. The complexes must be strong enough to be controlling; they must be so limited and completed that they are as useful as possible; they must be as general in their application as the environment warrants and as interconnecting and transferring elements can make them. Accordingly in the

[2] See page 4 for discussion of "distinguishing method".

analysis of these complexes in Chapter 5, there will be found strengthening and counteracting elements to make the complex controlling, completing and limiting elements to make the complex useful, and interconnecting and transfer elements necessary for their general application. At the end of Chapter 5 is a recapitulation wherein will be found an inclusive assembling of all contributing elements according to their distinguishing suggestiveness and according to the frequency of their recurrence in the analysis.

Mention has been made of the need for a selection between immediate, revived, and assembled experiences. Attention might also have been called to the fact that an avoidance of distracting realizations is advantageous in fixing desirable realizations. This matter of fixing realizations is of tremendous importance because of the range and recurrence of realizations in conduct control. Two of the seven complexes under consideration are composed entirely of realizations. It is therefore of paramount importance that a teacher of physics decide the basis upon which he or she shall select the kind of realizations to be presented. Shall they be immediate, personal experiences in the form of a laboratory experiment or shall they be assembled experiences invoked by the teacher in a demonstration method?

Without experimentation scientifically controlled, no satisfactory answer can be made either to the question stated above or to the many problems inherent in the establishment of controlling complexes. Ultimately experimentation must determine the extent to which each control element actually becomes controlling, useful, and generally applied in every-day experience before a complex can be properly defined and orientated for its most useful application. It would, therefore, be extremely unwise to undertake such an analysis as is found herein without accompanying it with an exemplification of the kind of experimenting that must at every turn supplement the analysis. An investigation is included both for its results and for its part in emphasizing the impossibility of an ultimately satisfactory analysis without experimentation of the kind illustrated.

In Chapter 6 will be found the procedure and the results of an

investigation conducted by the writer to determine the relative value of a laboratory method and of a "developmental-demonstration" method with reference to efficiency in building up certain realizations in the minds of the pupils. Six experiments of as many different experimenters were reviewed in order that the investigator might profit by their experience. The bibliography contains reference to these investigations as it does to all other literature mentioned in this book.

The procedure followed in the actual experimentation is strictly in conformity with the principles that guide Dr. Yocum's seminar group in investigations of a similar nature.[3] A trial experiment was carried out in detail, about one year previous to the conducting of the experiment reported, with the helpful criticisms of the seminar group mentioned, of which the writer was a member. Two groups of comparatively equal ability in the trait in question, as disclosed by preliminary tests, were the subjects of the experimental factors. Basal, or initial,[4] and final tests were given and arithmetic means and medians were used as the measures of central tendency.

There is in the results a very well defined advantage in favor of the demonstration method indicated for the establishment of realizations. There is also an indication of a probable slight superiority of the demonstration method in providing for permanency of realizations. The investigator does not presume any degree of finality in his results. He offers them to educators for what they are, a bit of evidence pointing to the demonstration method as the more efficient means of building up realizations, one of the most prevalent kinds of control elements found in the complexes under consideration.

The writer owes a debt of gratitude to many of his teachers in Columbia University and in the University of Pennsylvania. To Professor F. F. Good and to Professor A. I. Lockhart of Columbia University who, in courses in the teaching of physics and in the teaching of chemistry respectively, first stimulated

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[3] Suhrie, A. L. *The Inductive Determination of Educational Method.*
[4] McCall, W. A. *How to Experiment in Education,* p. 15.

the writer to thinking about aims and objectives in science. To Dr. W. H. Kilpatrick of Columbia, who is always an inspiration to his students in whatever field of education they may find themselves. To Dr. Arthur J. Jones in whose seminar at the University of Pennsylvania the objectives in the teaching of physics were investigated and finally to Dr. A. Duncan Yocum, without whose counsel this study would have been impossible.

II

Education as Conduct-control: the Determining Principles of the Analysis

Not much progress will be made in educational experimentation and research until those interested begin to speak in terms adequately defined and limited; until we build up an all-inclusive nomenclature that will suffice to convey meanings in a readily accessible manner; and until the modus operandi of education as conduct control is comprehended and accepted. It is the intent of this chapter to define terms used later in the analysis and to review the philosophy of education upon which the work has been based.

No longer are faculties of the soul held responsible for the conduct of the physical body. In their place have been substituted nervous reaction physiologically grounded in nervous tissue. The soul referred to by Aristotle has been divided and subdivided until today the ultimate source of conduct is to be found in the protoplasmic structure of a unit of nervous tissue, the neurone.[1] Neurones are much more definite and tangible than faculties; they lend themselves more readily to experimentation, and therefore are more productive of scientific results. As a consequence, there has been built up a theory in psychology that has wielded considerable influence in adjusting the curriculum of modern schools. Behavioristic psychology, as the new psychology is called, appeals to the understanding by reason of its indisputable advantages in accounting for the more simple manifestations of conduct.

"Ways of behaving"[2] depend upon the condition of the neurones involved in the act. Biological inheritance decrees action. Ways of action may be molded by education. To every stimulus presented to the nervous system of a living creature, some response will be made. Very frequently, however, the character of the response can be molded through learning.

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[1] Thorndike, E. L. *Educational Psychology*, Briefer Course, p. 84.
[2] Kilpatrick, W. H. *Foundation of Method*, p. 102.

It is this transforming of the character of responses that is the business and the only business of education. Out of a multiplicity of possible responses a desirable reponse must be chosen and made habitual. If it be desirable that the sight of a barometer produce concern about the weather rather than about the length of a glass tube then that response must be developed with the proper consideration for the laws that govern learning.

According to Thorndike, there are three cardinal laws that govern learning, that are operative in the fixing of responses—the law of readiness, the law of effect, and the law of exercise.[3] The desirable response to the sight of the barometer is much more easily and permanently fixed if the mind of the pupil is made ready for the response by some vital concern in the weather (law of readiness), if determining the weather forecast produces a satisfying mental state (law of effect), and if the response is repeated at sufficiently frequent intervals (law of exercise). Complicated as the theory becomes in the more intricate actions of human nature, in the more simple responses the explanation is clear-cut.

The scheme is simplified when we think of single responses made to specifically definite stimuli and represent the whole process in an S-R bond relationship. The "S" represents a stimulus, vibrations of one kind or another which are capable of being registered by one of our six senses; the dash represents the total nervous reaction that produces response; and the "R" represents the response, itself.

Reflex actions illustrate S-R bond relationships in an uncomplicated manner. It takes just 3-100 of a second for the customary response of the well-known knee reflex. But during that time the nervous impulse has travelled with the speed of electricity over a path leading from the knee to the spinal cord and back to the muscle of the leg. The response to the stimulus is determined by the nature of the bond which in the case in question is a very strong instinctive one. Not so with all S-R bonds. To move the hand at the sight of a signal requires five times the length of time and much more voluntary attention

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[3] Thorndike, E. L. *op. cit.*, pp. 131–132.

to the task at hand than the time and attention required for the simpler knee reflex.

What response does the sight of a whip produce upon the family pup? The answer does not much depend upon the breed of dog, but rather upon the kind of response that has previously been built up in the nervous system of the animal to the sight of a whip. Whether the dog attempts to jump over the whip or begins to whine or goes straight to bed is a matter of the condition of the neurones established throughout the life history of the dog. As a matter of common knowledge, a whip can be made a very potent factor in the life of a dog. Nor is it necessary at all times that the whip be in view. The voice of the master is later sufficient to produce the same desirable ends. Through the process of association, stress has been shifted from one factor of the total stimuli to another and a desirable response is produced in a simpler fashion than otherwise possible. This last phenomenon of associative learning[4] is a very important discovery of experimental psychologists frequently too lightly considered by educational theorists who have sought to apply functional, behavioristic psychology to schoolroom procedure.

Attention has been riveted on the stimulus—the immediate situation—with not enough emphasis on the possible forms of response either final or immediate. The result has been a serious menace to efficiency in instruction. If there is no other way to curb the pup than that of carrying a whip to furnish the necessary stimulus then surely the whip must be carried. But if the master's voice can early be substituted for the whip, efficiency demands the substitution. If there is no other way to teach the child moral reactions to the myriad of human situations than by producing each situation in turn, preparation must be made to run through the whole gamut of situations, making each reaction permanent by judicious application of the laws of readiness, effect, and exercise. If, however, a score of situations (be they immediate, revived, or assembled) will suffice to shift attention to a common factor in each of the situations then plainly efficiency demands that the common factor be made significant as quickly as possible.

[4] Woodworth, R. S. *Dynamic Psychology*, p. 81.

It is with the emphasis placed on the significance of the frequently neglected common factor that Dr. Yocum of the University of Pennsylvania has advanced his analysis of education as conduct control. The aim of education is the control of conduct—the control of thought and feeling as well as of overt action. Physics as any other subject is worse than useless unless it can make a contribution to this end. But Dr. Yocum maintains that there is a more helpful way of considering the task of education than as that of furnishing thousands of immediate situations in order to select and make permanent the socially desirable response to each one of them. No argument with behaviorism is called for. As a matter of fact, functional psychology is the working hypothesis of Dr. Yocum's conception of education as conduct control. The emphasis, however, is away from the immediate situation as the important factor in the formation of a desirable S-R bond. The determining stimulus does not necessarily claim the totality of an immediate situation. "Of the connections to be studied in man's learning an enormous majority begin with some state of affairs within the man's own brain—are bonds between one mental fact and another."[5]

Animal psychology deals in S-R relationships as simple as the knee reflex mentioned above. The human mind presents problems that insist on further explanation. Human understanding represents for the present at least the culmination of the evolution of intelligence. In human psychology, therefore, the stimulus and the response as well as the interlinking bond must be a much more subtle if not more elusive thing than in any other form of animal psychology. Efficiency in method demands a thorough search for interpretations of theory that will not encumber the work to be done. The power of an ideal does not lose any of its potency simply because the S-R bond relationship becomes complicated.

Accordingly Dr. Yocum has attacked the problem from a different angle. What is it that is finally controlling in human conduct? The power of a realization, an attitude, a standard, an idea, a habit. All of these controlling influences or stimuli, he

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[5] Thorndike, E. L. *op. cit.*, p. 174.

has analyzed and allocated into five different forms of control, depending for their classification upon their suggestiveness and the method by which they must be built up.

Throughout the discussion, it must be remembered that these control forms are not merely arbitrary divisions corresponding to educational functions, but depend for their existence upon their distinguishing suggestiveness and their distinguishing method. As explained in Chapter 1, by distinguishing suggestiveness is meant the peculiar *way* in which the control functions or *becomes controlling*. Impressions control through *feelings:* the distinguishing suggestiveness of impression control, therefore, is a "sensation or a *feeling* permanent enough and strong enough to exercise a continuing control." By distinguishing method is meant the peculiar manner in which the control is assured. This manner or method of establishing a control is finally determined only by experimentation. Impressions are established by cumulative instruction and cumulative experience: the distinguishing method of impression control, therefore, is "cumulative instruction and cumulative experience."

Likewise the elements under each control are justified through their distinguishing suggestiveness and their distinguishing method. Realizations, for instance,—one of the five elements under impression control—are defined for the purpose of the analysis by their feelings of familiarity; the method of establishing them calls for immediate personal experiences, revived personal experiences, or assembled personal experiences; selective realizations; and an avoidance of distracting realizations. Again the reader should be reminded that the distinguishing method is determined by experimentation.

"Knowledge as 'education' as distinct from knowledge as 'learning' or objectively organized knowledge, is the conscious retention by the individual of some experience, which suggests something strongly enough and permanently enough to control his future conduct." Knowledge is perceived as made up of S-R relationships, many of them purely mental reactions. The five different forms of control depend upon the degree of retention in the nervous tissue of these S-R bonds. Certain S-R bonds may have once been strong but now entirely obliterated

from the brain. Have they left an effect? Just as surely as the sketch lines of an artist affect the finished masterpiece. The smaller s-r reactions make possible more prominent S-R reactions long after the less significant have disappeared. Dr. Yocum, therefore, recognizes that corresponding to degrees or forms of retention are definite forms of control as follows:

FORMS OF RETENTION	FORMS OF CONTROL
1. Forgotten knowledge or experience	1. Impression
2. Barely retained knowledge or experience	2. Vocabulary
3. Many-sided knowledge or experience	3. Variation
4. Definite and certain knowledge or experience	4. Habit and System
5. General knowledge or experience	5. Transfer

Barely retained knowledge or experience may very frequently act as a stimulus to an S-R bond as truly as the physician's mallet occasions the knee reflex. Barely retained knowledge may be made controlling through a vocabulary conspicuously labelling experience. If, years after the study of a subject, the word physics, suggests the words mechanics, heat, light, and electricity, with two sub-divisions under each caption, some good has been accomplished; for these words themselves, labelling as they do past experience, will stimulate the normal mind to further action.

Many-sided knowledge and experience is another form in which S-R bonds may be retained. The behaviorist speaks of mind sets and of their influence in determining action either mental or physical. The fact which many schools of psychology have recognized is that single ideas even though unrelated in meaning are frequently influential in determining conduct. The cinema and radio are enriching the minds of all classes with a wealth of miscellaneous information and varied vicarious experience never before possible. The evaluating and coordinating of this material is the challenge for instruction. Physics teaching affords opportunity for the provision of a wealth of varied experiences and ideas by which, later in life, new experiences may be interpreted. To cite just one instance, the principle of expansion and contraction of metals will explain the sagging of telephone wires, the cause

of the rise of mercury in the thermometer, and the necessity for tuning a piano with the change of seasons, among a host of other physical phenomena depending upon the same principle.

Under definite and certain knowledge and experience is found the knowledge and experience necessary in the pursuit of one's vocation. Nothing can be left to chance in training for vocational efficiency: the S-R bonds must be exact and permanent. If the student is to be an engineer, the correct use of physical formulas is particularly significant to him—as significant as the definite knowledge needed in the ability to read and write.

General knowledge and experience, the last form of retention listed, represents that knowledge and experience which all individuals need to the end that community life be possible. Some understanding of the vastness of the heavens, of the principles of radio, of the laws of the commonwealth, of the history of civilization, of the need for government, is necessary for the edification of society if not for its stabilization. The minimum essentials of our elementary grades find their justification in this General Knowledge and Experience. The greatest use for General Knowledge and Experience is in establishing Transfer Control, "the carrying over of any habitual control into some new type or field of application or new situation where there are difficulties in the way of application, or where it cannot be applied without certain difficulties being met."[6]

Corresponding to these five forms of retention are the five forms of control. An analysis of the five forms of control presents a most helpful approach to the problem of making any subject in the curriculum contribute its part to the control of conduct. The analysis will follow immediately:

I. *Impression Control*

1. Sensings
2. Realizations
3. Attitudes
4. Standards
5. Motives

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[6] Yocum, A. D. *Analysis of Education as Conduct Control*, p. 41.

II. *Vocabulary Control*

1. Words Readily Retainable
   a. Through conspicuous labelling of conspicuous and accessible experiences.
   b. Through conspicuous and impressive elements in their own form.
   c. Through making conspicuous their similarity to familiar words.
2. General terms.
   Through memorizing, classifying, and assembling.
3. Locations.
   Rich in words through locating and interrelating.
4. Word suggesters.
   Through memorizing and practice in applying.

III. *Variation Control*

1. Temporary experiences suggestive of many ideas
   a. With many things specifically relatable to them. (Through problem project.)
   b. Specifically relatable to many things.
   (Through suggestion and retainable presentation.)
2. General Ideas.
   Through practice in classifying and assembling.
3. Permanent Locations.
   Rich in association, through practice in locating and interrelating.
4. Idea suggesters.
   Through memorizing and practice in applying.

IV. *Habit or System Control*

1. Habits essential to other controls.
2. Habits specifically useful in themselves
   a. Words and definitions
   b. Propositions, rules, and proverbs
   c. Literary masterpieces and quotations
   d. Skills
   e. Processes and procedures

V. *Transfer Control*

1. General favorable conditions in other forms of control (outside the things to be transferred) to meet new situations.
   a. Interest in many things, through their sensational or emotional appeal.
   b. General many-sidedness of interest.
   c. General system based on relative usefulness.

2. Specific associations memorized or assembled about the thing to be transferred.
   a. As general a form as is useful
   b. A controlling wish to transfer it
   c. Its association with the most useful fields and types of application.
3. Specific associations memorized or assembled about the most useful fields and types of application.
4. Practice in looking for new applications.

Impression control provides for the functioning of forgotten knowledge and experience; forgotten in the sense that the specific S-R relationship has been wiped from the surface of the brain, like the sketch lines of a finished masterpiece, but the more intangible S-R bond, the bond represented between some factor common to hundreds of situations and a desirable response, appears in the form of an impression control, the first control of the analysis. Probably the most important phase of the work of formal instruction is to be found under this form of control and most certainly is it the most neglected feature of classroom procedure. To teach people how to think is a much more popular objective than to teach people how to feel. And yet, "a man convinced against his will is of the same opinion still." The world has long ago recognized that emotions dominate intellect in the vast majority of instances. Realizations, attitudes, standards, motives are recognized by some educators as concomitant learnings,[7] but they are not stressed as forcibly as Dr. Yocum's analysis would warrant. It is extremely important in the teaching of physics as in the teaching of any subject in the curriculum that attention be paid to the fixing of desirable impression controls.

Vocabulary control emphasizes the great power for good that attention to words and word systems guarantees. Most people think with words, the symbols of ideas.[8] Does educational practice then attend sufficiently to the learning of the words peculiar to a subject that will assure conduct control in years to come when knowledge less suggestive shall have passed out of ken? It is possible to build up in the mind of the pupil a

[7] Kilpatrick, W. H. *op. cit.*, p. 275.
[8] Dewey, John. *How We Think*, p. 170.

system of meanings and ideas crystallized in words that will have an influence on conduct whenever that system is brought into play through some external stimulus.

Variation control, as the analysis above indicates, includes elements of control that arise through the learning of a miscellany of S-R bonds of the more abstruse kind. This kind of stimulus and response may be likened to the "ideas" of Herbart. All of us have very definite ideas that are very definitely controlling. The idea that health is the corner-stone of successful living is everywhere in this country influencing school policy today more than ever before. The same idea is having tremendous influence on personal conduct and in advertising circles is known to have one of the strongest appeals of all ideas productive of sales[9]. No organized attempt, however, to provide for the most useful elements of variation control is now found in the curriculum.

Habit and system control suggests among other values vocational training and technical skill. The first six grades of our school system are chiefly concerned with teaching the "tools of learning," the habits and systems essential to progress in the higher grades and in life itself. When one considers how much of our living is the manifestation of habits old or new, one can not but recognize the importance of making an inclusive list of all desirable habits and of incorporating these habits by conscious practice. The work of Franklin Bobbitt, William W. Charters, and Arthur J. Jones has shown the way to the assembling of such a list.

Transfer control provides for the carrying over of a reaction learned in one field of activity into another field of activity in the face of difficulties. Conscious effort is an essential in transfer. The curriculum must provide places where this conscious effort to carry over a way of acting in one field to another field will be given recognition. Nor should conscious effort be left to chance but rather must provision be made for reminders to try to transfer the reaction.

The analysis found in Chapter 5 must be interpreted in the light of the theory of education explained above. No radical

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[9] Starch, Daniel. *Principles of Advertising*, p. 273.

departure from the well-founded tenets of behavioristic psychology is involved in the conception of education as conduct control upon which the analysis has been based. The extreme behavioristic psychology calls for the stressing of the immediate situation as the indispensable condition of the educational process. The theory of education propounded by Dr. Yocum and submitted in this chapter stresses intermediary stimuli which may be built up between a factor common to hundreds of situations and the desirable response. An understanding of this conception of education as conduct control and of the nature of a complex as explained in Chapter 4 is vital for an appreciation of the analysis.

III

Selection of Objectives

In listing valid objectives for any subject of a curriculum, relative significance as indicated by range and recurrence and emotional appeal to the pupil or by unique value,[1] must determine what is to be included. Thomas H. Briggs puts the same principle in different words when he suggests that we ought "to teach pupils to do better the desirable activities that they will perform anyway, and to reveal higher types of activities, and to make these both desired and to an extent possible."[2] What knowledge is of most worth depends upon the need for that knowledge in the future, the number of times controls depending upon that knowledge for their vitality will come into play, and the significance for the happiness of the individual of the absence or the presence of that control. Reactions which are desirable should be taught in such a manner that they will have the greatest emotional appeal. Reactions which can be applied in establishing a number of control elements by right of their usefulness should be given priority.

Three well-founded approaches may be employed in an inclusive assembling of objectives of instruction: (1) Accepted purpose, (2) Social demand and need, (3) Scientific determination. All three approaches are simply categories of the more fundamental principles of range and recurrence and emotional appeal. If an objective is generally accepted as valid, the fact itself is an indication of a high degree of probability that the objective has social demand and need or a scientific significance. There are, however, objectives which science and society render valid, but which are not as yet items under purposes accepted by those who determine practices in the school. Science proved the validity of physical education as an educational objective long before anything approaching adequate provision for physical education was attempted in public secondary schools.[3]

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[1] An objective has unique value if it is necessary and if nothing else can take its place.

[2] Briggs, T. H. *The Junior High School*, p. 157.

[3] Inglis, Alexander. *Principles of Secondary Education*, p. 641.

Before any inclusive assembly of objectives with a view to selection can be considered as perfected, all three approaches must be utilized and the criterions of range and recurrence and emotional appeal must be applied. When to accepted purposes the objectives made mandatory by social demand and need and by scientific determination have been added and each of these objectives has been established in consideration of the principles of range and recurrence and emotional appeal, then a more complete assembly of valid objectives will have been made for the subject in question and for the social environment considered.

The assembly found in this piece of research is not all-inclusive. It contains only objectives which have been included among accepted purposes as revealed by a search through thirty-five professional articles on the objectives of science teaching. Four of the articles were based on the questionnaire method of determining prevalent objectives. The first article tabulated in Table 1 is the report of a questionnaire sent out by the Commissioner of Education in 1878 to all of the secondary schools of the country. R. E. Clark of the University of Cincinnati formulated the conclusions reported in the article. The second article tabulated in Table 1 is the result of an investigation by Charles K. Wead of the University of Michigan, 1884, of the opinions of teachers and practices of secondary schools throughout the country and Europe in the teaching of physics. The eleventh article tabulated is the result of an investigation conducted by H. A. Green working in the University of Iowa by means of a questionnaire sent out to 391 high schools in the country in 1917 (101 physics teachers replied), and by means of an investigation of courses of study. The fourth questionnaire investigation was made by Leonard Koos for the use of the Committee on the Reorganization of the Secondary School and the Definition of the Unit of the North Central Association of Colleges and Secondary Schools in 1917. One hundred and thirteen teachers of physics replied to the questionnaire dealing with physics teaching.

The other articles reviewed are catalogued in detail in the bibliography. They represent the opinions of leaders in the

field of education and of teachers of science. The report of Otis W. Caldwell and committee on the Reorganization of Science in Secondary Schools, 1920, is significant for the fact that it is the crystallization of the opinions of forty-seven leaders in education most of them having served at one time or another in the capacity of public high-school teachers. The list includes Otis W. Caldwell and Thomas H. Briggs of Teachers College, Columbia University; C. D. Kingsley, state high-school supervisor, Boston, Mass.; Mabel Peirson, Pasadena High School, Cal.; G. R. Twiss, Ohio State University; and R. H. Williams, Scarborough School, N. Y. Other reports include the names of H. N. Chute of Ann Arbor High School; Fernando Sanford of Leland Stanford University; C. R. Mann of the Educational Division, U. S. War Department; and John Dewey of Columbia University.

Table 1, page 28, gives a record of the frequency with which various objectives were mentioned in thirteen of the most pertinent articles reviewed. Every objective mentioned in the thirty-five articles has been listed below: not one has been left out of the reckoning. Many of the objectives enumerated may be considered as subsidiary to other objectives more general in their application. An attempt has been made by the writer to classify in Table 1, such subsidiary objectives as might come under the major head of scientific attitude.

List of All Objectives Found in Articles Reviewed

1. To teach the laws of nature
2. To make men better able to live well
3. To develop the scientific attitude
4. To impart knowledge necessary for other sciences and college
5. To teach students to observe
6. To teach students how to reason
7. To teach students how to check conclusions by further testing
8. To develop the power of thinking
9. To teach the experimental method

10. To make students realize that truth does not depend upon authority
11. To inculcate the spirit of inquiry in the minds of children
12. To teach children how to draw conclusions
13. To make pupils attentive to detail
14. To teach pupils how to measure
15. To teach pupils how to weigh
16. To teach pupils how to compare
17. To teach pupils how to analyze data
18. To develop habits of scientific imagination
19. To impart ability to exercise and control imagination
20. To produce self-elimination
21. To stimulate mental rectitude
22. To permit pupils to test natural laws for themselves
23. To impart skill and acquaintance with use of apparatus
24. To inculcate respect for precision
25. To cultivate precise language
26. To cultivate neatness in papers
27. To teach conservation in drawing conclusions
28. To teach persistence
29. To create a form of veracity, the acknowledgment of difficulty
30. To foster common sense, good judgment
31. To make one truly religious
32. To substitute exact definitions for hazy notions
33. To give pupils an understanding of the rules of the game of life
34. To give the student vocational and avocational habits, skills, interests, and knowledge
35. To explore the interests, aptitudes, and abilities of pupils
36. To give mental discipline
37. To form systematic habits of work
38. To create the ideal of suspended judgment
39. To create the ideal of open-mindedness
40. To create the ideal of the just weighing of evidence
41. To formulate ideals of impartial observation and impersonal judgment
42. To develop the emotion of wonder
43. To impart the ability to deal effectively with matters of mechanics, heat, electricity, light, sound, etc. as these are involved in the performance of unspecialized practical activities
44. To foster the ability to participate in a civic way in the directive and inspectional public opinion that provides the ultimate control over specialized service agencies and labors which have to do with involving practical science factors (city water supply).

TABLE I (Explanation on following page)

A Tabulation of Objectives With a Record of the Typical Frequency With Which They Were Mentioned in the Articles Reviewed

Objective	Article												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. The Scientific attitude						×	×	×			3	4	2
To observe	×	×	×	×	×	×	×			×			×
To reason		×	×	×	×	×	×						×
To check conclusions		×				×							×
To develop power (thinking)		×		×									
Experimental method	×					×				×			
Authority not basis		×	×										
Attention to detail			×							×			
To measure			×	×						×			
To weigh			×	×						×			
To compare			×	×						×			
To analyze data			×	×						×			
Develop imagination				×			×						
Self-elimination				×									
Suspended judgment (ideal)						×							
Open-mindedness (ideal)						×							
Impartial observation (ideal)						×							
2. To relate the subject to problems of environment		×			×			×	×		1	1	1
3. To make men better able to live well		×					×				2	2	
4. Familiarity with subject matter											5	3	3
5. College entrance		×									4	5	
6. Vocational knowledge	×	×					×						
7. Mental discipline	×	×						×					
8. Exploratory value		×											
9. Systematic habits of work			×										
10. Develop emotion of wonder						×							
11. To make men religious							×						
12. To develop common sense							×						
13. To develop a form of veracity		×											
14. Stimulate mental rectitude				×			×						
15. To test laws of physics					×								
16. To develop skill in use of apparatus					×								
17. Respect for precision		×								×			
18. To foster precise language			×	×			×		×				
19. To foster neatness in papers			×							×			
20. To foster conservatism in conclusions							×						
21. To develop persistence							×						

45. To foster the ability, disposition, and habit of diversified observation of the endless physical phenomena which are ever present before one's eyes as an enjoyable and fruitful life-long leisure occupation
46. To foster the ability, disposition, and habit of reading as a life-long indirect mode of observation of physical phenomena, also a leisure occupation.
47. To impart an intellectual vision and apprehension of the world of matter, force, and physical phenomena in the midst of which one lives and acts
48. To foster an enlightened religious consciousness
49. To foster respect for scientific enterprise.

Explanation of Table No. 1

The series of numbers at the top of Table No. 1 (1–13) represents an arbitrary labelling of professional articles as follows:

1. Results of questionnaire investigation by R. E. Clarke.
2. Results of questionnaire investigation printed by C. W. Wead.
3. Article entitled "Suggestions for Laboratory Work" by H. N. Chute.
4. The Teaching of Physics, Smith and Hall.
5. Physics in the High School, C. A. Long.
6. The Teaching of Physics, C. D. Mann.
7. The Teaching of Science, J. F. Woodhull.
8. How to Study Illustrated through Physics, F. Sanford.
9. Practical Physics, A Text, Black and Davis.
10. The Reorganization of Science in Secondary Schools, Otis Caldwell and Committee.
11. Results of a questionnaire investigation found in "The Status of the Sciences in North Central Schools," a thesis, by H. A. Green of the University of Iowa.
12. Results of an investigation of courses of study made by H. A. Green in the same thesis.
13. Results of a questionnaire investigation reported by L. Koos in The Administration of Secondary School Subjects.

The sign (x) marks the occurrence of the objective printed to the left.

For instance, article 8, "How to Study Illustrated through Physics" has listed but three objectives, namely, the scientific attitude, the relating of the subjects to problems of environment, and mental discipline. Articles 11, 12, and 13 evaluate the objectives considered. Instead of an x, therefore, a number has been substituted to represent the rank of the objective as determined by the questionnaires considered. For instance, the objective,

'To relate the subject to problems of environment" was found to be the most commonly accepted purpose in all three of the investigations, 11, 12, and 13.

The articles mentioned are catalogued in detail in the bibliography.

An examination of Table 1 will reveal that the development of the scientific attitude is one of the most prevalent objectives found in any of the thirteen articles tabulated. "To relate the subject to problems of environment" is another prevalent objective. These two with a third, "To make men better able to live well", are more frequently mentioned than any other. Being more frequently mentioned than any other, these three objectives form the basis in accepted purposes upon which the outcomes have been established and analyzed. The emphasis on development of the scientific attitude justifies its inclusion as an outcome to be analyzed. "To relate the subject to problems of environment" suggests the fifth and sixth outcome found in the analysis as listed on page 33; namely, "A realization of the relation of physics to the home" and "A realization of the relation of physics to commerce and industry." Under the purpose, "To make men better able to live well", the other outcomes analyzed find their justification: a standard of strength of character, an interest in science, a regard for the common welfare, and an attitude of respect for the spirit and service of science. Two of these, a Regard for the Common Welfare and a Standard of Strength of Character, are further justified for inclusion through consideration of the results of a questionnaire investigation of Dr. Yocum.[4] The recapitulation on page 59 reveals the frequently occurring necessity for "an attitude of respect for the spirit and service of science" in order to establish the other outcomes.

From the point of view of accepted purposes, therefore, there is adequate justification for inclusion of the scientific attitude, a realization of the relation of physics to the home, and a realization of the relation of physics to commerce and industry. There

[4] Report of the committee on the Teaching of Democracy, a reprint of section of Vol. 61 of *Addresses and Proceedings of N. E. A.*, 1923, p. 5.

is also sufficient indication of the advisability of including a standard of strength of character, a regard for the common welfare, an interest in science, and an attitude of respect for the spirit and service of science.

It should be noted at this point that usually the objectives as found in a list of accepted purposes must be translated into terms of mental characteristics, outcomes, before a useful analysis can be made. Accordingly, "to relate the subject to problems of environment" becomes translated into realizations, a "realization of the relation of physics to commerce and industry and a "realization of the relation of physics to the home." The "scientific attitude", however, remains as such because it is stated in terms of a mental characteristic, an attitude.

To show that the outcomes listed at the end of this chapter have range and recurrence in accepted purposes is the intent of Table 1 and its accompanying discussion. A count of the actual range and recurrence in social demand and need and in scientific determination has not been made. By determining the range and recurrence of each of the outcomes in a random sampling of actual situations representing modern living in its desirable phases, the given outcomes may be scientifically evaluated. Bobbitt's[5] work with the curriculum as well as that of Charters[6] illustrates the kind of procedure necessary in such an undertaking. Social demand and need and scientific determination is and by right should be acid tests for sound objectives. When the need for certain ways of acting is continually recurring, however, there is no imperative occasion for an exact count of the number of situations in which such need is manifested.

As for the analysis itself, every outcome and control element has a unique contribution to be received from the teaching of physics. The writer does not for one moment mean to say that every outcome or control element mentioned is unique for physics[7] and for physics only or that other subjects may not have contributions to make to the outcomes. There are three senses in which uniqueness may be involved in an outcome.

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[5] Bobbitt, Franklin. *The Curriculum.*
[6] Charters, W. W. *Curriculum Construction.*
[7] Eikenberry, W. L. *The Teaching of General Science,* p. 40.

(1) The actual outcome may be unique as when we set up as an objective the imparting of skill in measuring air pressure. (2) Physics teaching may have a unique rôle to play in accepting responsibility for correcting or counteracting any chance outcomes peculiar to the teaching of physics—science tends to materialism unless provision is made for correctives. Or again (3) physics may be able to interpret some fact in life in a uniquely potent fashion: it may afford a place in the curriculum where a certain outcome can be most adequately or most efficiently fixed. Manifestations of the force of gravity when assembled as a part of physics teaching promote an understanding of the way in which the force acts in a more efficient maner than is possible in any other branch of learning. Every outcome and control element mentioned in the analysis is uniquely an outcome for physics in one or more of the three senses enumerated.

Below will be found a list of the seven outcomes analyzed later with the reasons for the inclusion of each one. There are perhaps other outcomes in the teaching of physics equally pressing in their challenge for analysis, but the search for accepted purposes has not revealed them in such a conspicuous fashion. The propaedeutic aim of education,[8] for instance, has been entirely neglected on just such a basis.

List of Major Outcomes Analyzed	with The Reason for Inclusion
1. The Scientific Attitude	Table 1 shows that it is specifically mentioned or implied in all but one of the articles reviewed. It is ranked 2nd in investigation 13, 4th in investigation 12, and 3rd in investigation 11, Table I.
2. A Standard of Strength of Character	Results of an investigation by Dr. Yocum in "Specifications for a Democracy" have established this outcome among accepted purposes in education.

[8] Inglis, Alexander. *Principles of Secondary Education*, p. 379.

3. An Interest in Science	Implied in Table I under "To make men better able to live well", the outcome is suggested in many of the articles and as an objective is ranked 2nd in investigations 11 and 12, Table I.
4. A Regard for the Common Welfare.	Results of an investigation by Dr. Yocum in "Specifications for a Democracy" have established the outcome among accepted purposes in education.
5. A Realization of the Relation of Physics to the Home, and 6. A Realization of the Relation of Physics to Commerce and Industry	Mentioned in many articles as shown in Table I. As an objective, ranked 1st in three investigations, 11, 12, and 13, Table I.
7. An Attitude of Respect for the Spirit and Service of Science	Suggested by objectives listed. Range and recurrence in necessary complexes for other six outcomes as shown in recapitulation on page 59 warrant its inclusion for analysis.

IV

Complexes

Objectives after all are simply objective—they are the logically analyzed ends existing independent of the individual learner. For teachers the most important thing to know about an education objective is the number and kind of education outcomes that will assure the objective in question; no objective is attained until there is established in the mind of the pupil an adequate number of the proper kind of control forms with their elements. The last objective listed on page 29 reads "To foster respect for scientific enterprise." In order "to foster respect for scientific enterprise" there must be built up in the mind of the pupil certain control forms and elements as, for instance: (1) a realization of the contribution physics has made to social and individual welfare, (2) a realization of the disinterested motive of pioneers in science, (3) a realization that commercial manifestations of scientific research depend upon what was in their time thought to be relatively insignificant discoveries, (4) a realization that the last fifty years has seen more material progress than that achieved before in the whole history of man, (5) an attitude of admiration for scientists' disinterestedness, and (6) an attitude of admiration for the wonders of the physical universe.

The sum total of these control forms necessary for the insuring of an objective is called a complex. Usually a complex is composed of many different forms of control with their corresponding elements. It represents a complexity of control forms all present in the mind of the pupil and all contributing toward the securing of the objectives specified.

Behavioristic psychology emphasizes the practicing of every desirable stimulus and response reaction in the category of living. The sole duty of education is to set up situations and to modify the responses thereto until desirable responses are the result. Practice of this S-R relationship then fixes the reaction for present and future use. As a means of controlling conduct,

the method has been justified through its works over and over again. If, however, it is the only method of molding human conduct, then schoolmen are limited rather hopelessly.

Fortunately, a complex once established normally guarantees more than one specific S-R reaction. An "attitude of respect for the spirit and service of science" will, when made as generally useful as possible, be determining, for a man who possesses the complex, in questions of accepting or rejecting unbiased testimony of experts; in situations demanding self-sacrifice for the common welfare; in the worthy use of leisure; and in attaching proper values to human enterprise. The complex itself built up as it is by specific S-R relationships soon overshadows future possible stimuli in any given situation and determines socially desirable responses. Thus it determines future action much more surely than an obvious stimulus involved in any situation.

Realizations, attitudes, standards, motives—all recognized as concomitant learnings by functional psychologists—are together with vocabulary, variation, habit and system, and transfer control the determinants of one's conduct. Combined in a thousand different ways, these control forms and control elements in a kaleidoscopic fashion compound a complex that works for the good or the harm of the person possessing it. Usefulness is a most important consideration in building up a complex. Complexes are daily developing in the nervous system; our duty to man and God is to consciously build desirable complexes rather than to allow accumulations of questionable ones.

A complex to be useful must be counteracted by other complexes; it must be strengthened by others; it must have as general an application as the environment warrants. A scientific attitude if not counteracted by a religious sense will subject its possessor to the danger of pessimistic skepticism. On the other hand, the religious feeling when not counteracted by a scientific attitude may easily lead to asceticism. The extent to which each complex should be employed is a matter which only experimentation can finally determine. That there is a limitation to the useful application of every complex has been frequently exemplified of late by men of strong religious convictions who have sought

to banish the discoveries of science by exterminating pages of text-books.

Within the complex itself, three general classes of elements make the complex useful.

1. There are the Strengthening and Counteracting Elements. A realization of the purpose and order and beauty in the universe strengthens the religion complex: the scientific attitude counteracts a tendency to fanaticism. Both of these elements should be found in the religion complex.

2. There are the Completing and Limiting Elements. The nature of the outcome determines just what the completing and limiting elements are to be. In Complex 2 of the analysis in Chapter 5, A Sense of Precision and a Sense of Confidence helps to complete A Standard of Strength of Character while a Sense of Humility is a limiting element in the same complex.

3. There are the Interconnecting and Transfer Elements. The scientific attitude, for instance, to be most useful must be interconnected with phases of living other than existence in the physics laboratory. A realization of the value of suspended judgment in business, in perplexing social problems, and in matters involving religious intolerance is of paramount importance. Under Complex 1 in Chapter 5 is found also transfer elements of the following nature: "Neatness in physics, chemistry, school subjects, one's vocation, dress, etc." It is necessary that the outcome carry over into all feasible phases of living in order that the complex be most useful.

The elements included under any one complex depend upon the kind of outcome involved and its distinguishing method. It is possible that a complex consist entirely or almost so of realizations. Another may include all control forms and elements. This is only another way of saying that each outcome has its own distinguishing suggestiveness and its own distinguishing method. The matter of distinguishing method has been mentioned before, but it is of such importance that the writer deems it advisable to quote Dr. Yocum once more in his conception of the distinguishing method of building up realizations, attitudes, and standards:

"A—The distinguishing method of developing a realization is choice among immediately personal, revived, or assembled, or imaginary experiences of those essential to the selected realizations and avoidance of realizations which distract attention and feeling from it.

1. Immediate personal situations or experiences.
   By these is meant currently occurring situations to which individuals or groups must personally adjust themselves.
   They may be ignored, seized upon, or created by the teacher.
2. Revived personal situations or experiences.
   By these is meant situations already experienced by individuals or groups, which they vividly recall as wholes, either for themselves or through the art of the teacher.
3. Assembled situations or experiences.
   An assembled situation is one not personally experienced as a whole, but which is made personally real through a reassembling of past personal experiences in a new combination.

B—The distinguishing method through which attitudes are to be made controlling or their harmful control counterbalanced, is:

1. Building up of strong enough useful feelings about the things which should be made emotionally controlling because they have the greatest range and recurrence in life.
2. The definite centering of already existing strong feelings upon useful ideas.

C—The distinguishing method of developing standards is to build up strong enough motives to ensure a controlling wish to attain them; to ensure through experience an attitude of self-confidence in one's ability to attain each successive step; to provide through reminders to try, effective means of ensuring continual enough recollection of the controlling wish accompanied by the necessary effort; and repeated enough practice to ensure highest effort at attainment for each step toward the standard."

Listed below are the complexes which this thesis seeks to analyze into their various strengthening and counteracting elements, their completing and limiting elements, and their interconnecting and transfer elements. They form a list of outcomes to which physics teaching should contribute. It is not an all-inclusive list, and yet, suggested as it was by the list of accepted objectives, the successful establishment of these complexes will accomplish the great majority of the objectives enumerated on page 26. Just how many of the objectives these

complexes will ensure, awaits extensive experimentation under scientifically controlled conditions.

The complexes analyzed in the next chapter are as follows:

1. A scientific attitude,
2. A standard of strength of character,
3. An interest in science,
4. A regard for the common welfare,
5. A realization of the relation of physics to the home,
6. A realization of the relation of physics to commerce and industry,
7. An attitude of respect for the spirit and service of science.

The scientific attitude when once established in the mind of a pupil will provide for the habit of suspended judgment. It is a feeling about the passing of judgment strong enough and permanent enough to cause the individual to verify his conclusions wherever the need for verification is indicated. The third complex mentioned, "an interest in science", should in no way be confused with "a scientific attitude": they are complexes entirely different in function. A scientific attitude controls one's conduct in matters involving judgment: an interest in science establishes a mind set which among other results determines to a certain extent one's behavior in leisure. An interest in science frequently results in making some branch or form of science a hobby. "An attitude of respect for the spirit and service of science", being also an attitude, may possibly run the risk of being confused with the first complex. The difference, however, is plainly discernible in the functioning of each. Respect for the spirit and service of science does not materially contribute toward the practice of suspended judgment, but it does establish a close relationship between the layman and the scientific expert, tends to establish faith in the expert, and promotes scientific research.

The second complex, "a standard of strength of character", is illustrative of another one of the control elements under Impression Control. As a standard the complex represents permanent feelings which result in continuing effort to attain a higher level of achievement in qualities suggested by the name of the outcome—in this instance, strength of character. The complex, as Chapter 5 reveals, is composed of Sensings, Realizations,

Attitudes, and other Standards. The fourth complex, "a regard for the common welfare", has been included on account of the significance of the contributions which the teaching of physics may make to the complex. The fifth and sixth complex need no particular attention at this time.

V

Contribution of Physics to Complexes Selected

Complex 1

The Scientific Attitude

The results of the questionnaire investigations of H. A. Greene, cited in another place, show that one of the most prevalent conscious aims of science teachers is to develop the scientific attitude. Training in observation, accuracy, and thinking is the key-objective as disclosed by the investigation of Leonard Koos, also cited before. E. E. Slosson in an address delivered during Schoolmen's week, 1926, in Philadelphia, spoke thus:

"The world, like a child at Christmas, is willing to receive the material gifts of science but refuses its moral lessons. The world will accept from the hands of science railroads and radios, soft raiment and foreign foods, airplanes and submarines, but turns a deaf ear when science would talk of peace, efficiency, economy, foresight, and the frank facing of facts.

* * * * *

We look to our teachers to cultivate the scientific habit of mind in the rising generation. It is among the most important and most difficult of our duties."[1]

Many of the elements essential to the scientific attitude considered as a complex will be found on the following pages. The unique contribution that physics can make to each element of control is indicated in the paragraph placed directly under the naming of each element. "Essential elements", as used, includes all three classes of elements described on page 36.

The Scientific Attitude

Essential Elements:

1. Attitude of wonder or inquisitiveness

(Developed by centering pupil's curiosity on mysteries of nature. The

[1] The Changing Mind of Man. *Schoolmen's Week Proceedings*, 1926, pp. 35–43.

hydrostatic paradox, phenomenon of air pressure, electrical results need not be fantastic but can be used to pique curiosity.)

2. Attitude of distrust in snap judgment

Fallacious theories explaining natural phenomena should be reviewed and the error of forming conclusions without testing them afterward emphasized.

a. The emission theory of light
b. The phlogiston theory of heat
c. "Nature abhors a vacuum"
d. Goethe's theory of color

3. Standard of verifying everything important enough to warrant verification. Achieved through a succession of attainable steps.

Contributory elements: (a) Realization of need of verification as illustrated in the doing of experiments in the laboratory, (b) A realization of the possibility of verifying everything that has been scientifically determined, (c) Realization that the scientist does not argue. He presents his facts and asks others to verify if they will. (d) A memorized general idea, "Verification wherever consequences harmful to self or to others may result from error."

4. Realization of the universality of cause and effect

Contributory Elements: (a) Realization of the difference between statutory law and natural law, (b) Realization of the order or sequence factor prevailing in natural law, (c) Realization of the inevitableness of natural law, (d) Realization that it is impossible not to obey natural laws.

5. Realization of the difference between the scientific method and the method of argument

a. Galileo's experiment vs. Aristotle's logic
b. Goethe vs. Newton
c. Tycho Brahe vs. John Kepler

6. Realization of the influence of prejudice

Faraday's "The Education of the Judgment": "That point of self-education which consists in teaching the mind to resist its desires and inclinations, until they are proved to be right, is the most important of all."

a. Galileo's spectators could not believe their senses because of their prejudice

7. Habit of seeking only the truth

Fostered by practice in the laboratory of selective observation

8. Realization of the vast change since 1600 attributed to the scientific method

9. Realization of the importance of the scientific habit of thinking

John Dewey, "One of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread and the

deepening hold of the scientific habit of mind; and that the problem of problems in our education is therefore how to discover and how to mature and make effective this scientific habit."

Roger Bacon, "We have three means of arriving at knowledge: authority reason, experiment. Authority has no value if its basis is not understood; it teaches nothing but merely calls out our assent. By reason we may distinguish a sophism from a demonstration, while we may test our conclusions by experiment."

Leonardo da Vinci, "In undertaking scientific investigations, I first plan a few experiments, because it is my desire to base the problem on experience and then to determine why the bodies in question are constrained to act in a given manner. This is the method that one must adopt in all researches."

(A centering of attention on the above statements will contribute toward the desirable realization.)

10. A memorized vocabulary sequence suggestive of manner of procedure in the scientific method and practice in its use.

The vocabulary sequence used by the writer follows:

a. Given	a. Definition of problem
b. Required	b. Search for solution
c. Formula	c. Elaboration of solution suggested
d. Substitute or	d. Verification by experimental evidence
e. Solve	e. Formation of conclusion in most general terms
f. Check	

(The second vocabulary sequence listed is suggested by John Dewey in "How We Think" and is most useful in abstract problems calling for mature minds.)

11, Realization that scientific judgments are suspended judgments. Under "memorized vocabulary sequences" the "elaboration of the suggested solution" and the "verification by experimental evidence" call for delayed decision.

12. Habits of selective observation.

Built up in the laboratory or in demonstrations by practice in looking for definite results. This consideration requires well arranged and elaborate laboratory instructions rather than a general exhortation to observe everything and anything within the compass of the room.

13. Habits of neatness, carefulness, accuracy.

Fixed by practice in specific situations and by conscious transfer abetted through word suggesters such as

Neatness in physics, chemistry, school subjects, one's vocation, dress, etc.

Contributory Element: Realization that we are prone to accept material blessings of science but neglect its spiritual lessons.

14. A miscellany of memorized general ideas (principles of physics as a part of variation control).

Results of scientific thinking are enriched through an augmenting of "the fund or store of experiences and facts from which suggestions proceed."[2]

A perspective is gained by such memorized general ideas from which may grow later a comforting philosophy of life.

15. A realization of the greater appreciation and enjoyment of living that comes through an interpreting of life's values in a scientific way.
16. A religious attitude (developed in another place)
17. A sense of the beautiful in natural effects
18. A realization of the present inadequacy of science in interpreting life.

Complex 2

Individual Strength of Character

Individual strength of character, as an educational objective, is in no way unique for physics, or for that matter, to any subject of the curriculum. Strength of character, however, is of paramount importance in any scheme of teaching and because of its importance no stone should be left unturned in search of a device that will promote the realization of such a purpose in education.

The phrase, individual strength of character, to label a complex that will assure desirable conduct, was suggested to the writer by Dr. Yocum, who has in his course on the Teaching of Democracy recognized strength of character as one of the specifications of a sound democracy. Its use in such a significance suggests more forcefully that in every analysis of outcomes its consequences demand attention. Whatever subject in the curriculum is under scrutiny, inquiry should be made into possible contributions to this specification of democracy, this all-important objective in education. That the objective is an accepted purpose is evidenced by the verdict passed on it by the group of distinguished Americans to whose judgment Dr. Yocum appealed.[3]

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[2] Dewey, John. *How We Think*, p. 30.

[3] Report of the committee on the Teaching of Democracy, a reprint of section of Vol. 61 of *Addresses and Proceedings of N. E. A.*, 1923, p. 5.

Physics, as other sciences, has its offering to make to this end, but it is most efficiently made when made consciously in terms of conduct-control, as realizat ons, standards, habits, vocabulary controls, etc. "Essential elements", as used, includes all three classes of elements described on page 36. Only experimentation can determine which or how many of the elements are required.

A Standard of Strength of Character

Essential Elements:

1. Realization of the power of perseverance.

"All the world steps aside for the man with a purpose." Histories of physical inventions (electric light, radio) should be used.

2. Sense of pride in achievement

Sense of happiness derived by doing a difficult task well. The course should include many problems real to the pupils and within their comprehension. Practice with satisfaction will contribute toward this outcome.

3. Sense of precision

Contributory elements: (a) A realization of the necessity for precision in making all physical measurements. (b) An opportunity to imitate instructor's regard for precision as illustrated in demonstrations.

4. Sense of confidence

Contributory element: (a) Standard of mastery to be attained through daily lessons well prepared. Homogeneous grouping makes possible the setting up of standards that are attainable.

5. The standard of clear expression

Cultivated by reminders to try through practice in the socialized recitation where there should be sufficiently strong motives to foster such a standard.

6. Knowledge of physics as a standard

By a gradation of subject matter from the psychologically simple to the more complex, attainable standards will be provided. Every motive not detrimental ought to be engaged: felt need, marks, desire to surpass one's past record, pride in achievement, etc. Class situations should furnish reminders to try.

7. Sense of humility

Contributory elements: (a) A realization of the difficulty involved in problems now solved by physicists will increase respect for mental acumen and

cause the possessor to better evaluate his own worth. (b) A realization that great scientists have been humble men. Excerpts from their writings are invaluable in contributing toward a sense of humility.

8. A religious attitude

Contributory Elements: (a) Realization of the inadequacy of materialistic theories of the universe is a strong contributory element. The final cause must be found in God. (b) Realization of the inexorability of natural law. Science of matter and of mind everywhere proclaims that whatsoever we sow that also shall we reap. (c) Sense of the immensity of the universe as determined by physical calculation. (d) Realization of the mysteries of the atom pointing the way to the unfolding of knowledge more bewildering than the tenets of faith have asked of man. (e) Standard of righteousness developed through realization that right is as fundamental as natural law. (f) Attitude of respect for men of faith who try to explain mysteries of nature. (g) Standard of toleration until experiment has proved the truth. (h) Realization of the significance of the conservation of energy principle when applied to the destiny of the mind.

9. Standard of truthfulness

"Tell the truth, the whole truth, and nothing but the truth" bears repetition time and time again as a reminder to try. All science is an attempt to find the truth and tell it. "Know ye the truth and the truth shall make you free."

10. Standard of self-sacrifice

Developed by familiarity with outstanding examples of self-abnegation found in pioneers in every branch of science. Counteracting element: A standard of self-realization which will serve to define and limit self-sacrifice to an extent that sacrificing will not prevent the realization of the noblest self.

Complex 3

An Interest in Science

Science is usually thought of as requiring rigorous self-abnegation, a barren and uninteresting location for humdrum, tireless investigation. Much of research is of course just that. There is, nevertheless, no reason why science cannot offer a live and permanent interest to the boys and girls of our schools who will soon be the men and women of our land with more leisure on their hands than has ever before been known in the history of modern times at least. Increase in crime and increase in leisure are marching hand in hand in America. Whether or

not there is a direct relationship between the two is at present only a matter of conjecture. There are criminologists who think they see a definite relation.[4]

At any rate, no one will gainsay the importance of filling our leisure hours with worth-while activity.

"In the stress of modern life, recreation is a real need. It is of the greatest importance to society that its members shall possess a stock of interests, tastes, and appreciations upon which may be found recreations of the higher type. Such is the appreciation of beauty in plants, animals, landscape,and all nature. In many cases the enjoyment may be founded not upon its beauty, but upon an understanding of its meaning. Thus, a journey across the alkali and sage-brush areas of the Great Plains may be very wearisome to the casual traveler, but intensely interesting to one who has sufficient knowledge of the geography and biology of the region to enable him to interpret the meaning of the formations he passes. . . . No subject in the curriculum is richer in recreative suggestions than science. Such interests are a needed antidote to the tendency toward sensual and vicious pleasures."[5]

Found among the objectives investigated, page 30, and suggested by students of sociology like the authorities quoted above, the range and recurrence of the outcome under consideration are apparent. The unique contribution of the study of physics to the elements enumerated is indicated in the paragraphs placed directly under each element. "Essential elements", as used ,includes all three classes of elements described on page 36. Only experimentation can determine which or how many of the elements are required.

An Interest in Science

Essential Elements:

1. Sense of pleasure in study of physical phenomena.

Contributory Elements: (a) Realization of the significance of the subject (complexes 7 and 8). (b) Imitation of teacher's enthusiasm, (c) Realization

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[4] Alger, G. W. Leisure—for What, *Atlantic Monthly*, April 1925.
[5] Eikenberry, W. L. *The Teaching of General Science*, p. 46.

of the presence of more or less permanent problems in physics. (d) Memorized general ideas that illuminate life's situations, such as

1. The principle of machines
2. The principle of flotation
3. Conservation of energy
4. Conservation of matter
5. Kinetic theory of heat

2. A sense of curiosity developed and stimulated by real questions:—

How can the thickness of a page be measured?

Why cannot the door of a closet be slammed shut?

Why do mechanics sometimes use wrenches with very long handles?

Why is it easier for a swimmer to float in the ocean than in a river?

Why does a rubber tube often collapse when the air inside is exhausted?

Why are deep water fish kept in specially fitted pressure tanks in an aquarium.

Why does a balloon rise?

Do wrecked ships go to the bottom or float around at a certain depth?

How can the altitude of an airship ascension be measured?

How does the physician measure a person's blood pressure?

Why does one lower the handle in pushing a lawn mower through tall grass?

Why does a train continue to move after the steam is shut off?

Should hot or cold water be used to wash a clinical thermometer?

Explain why pouring hot water on the neck of a bottle will sometimes loosen a glass stopper.

What does one mean by speaking of the cold getting into a house?

Why do glass bottles crack if placed on a hot stove?

Why a e the walls of ice houses often packed with sawdust?

What is the scientific fact back of the old saying that a "watched pot never boils"?

What is the use of a radiator on an automobile?

Will a magnet attract a tin can? Explain.

How does a fountain-pen filler work?

Explain why ice is placed near the top of a refrigerator.

Why does fanning cool a person?

Why is it that the clapping of your hand makes a noise and the waving of your arm does not?

Why does the pitch of a buzz saw fall as it enters a board?

What is a buzzer?

3. Sense of respect for experimentation.

Contributory Elements: (a) History of Galileo's proof of the laws of falling

bodies. (b) Realization of the nicety with which density of materials may be verified by experimentation. (c) By showing that experimentation is needed in physics, chemistry, medicine, government, matters of social welfare, this sense of respect may be made controlling by transfer. (d) Realization of the amount of experimentation necessary for the production of the perfection now found in the electric light bulb. (e) History of the investigation of the nature of thunder and lightning.

4. Realization that many of the changes about us are physical.
   a. Disolving of salt in water
   b. Freezing of water
   c. Fusion of iron
   d. Expansion and contraction of metals
   e. The production of colors in the sky

5. The habit of making physics a hobby.
   Developed by practice in a radio club, kodak club, or science club

6. The habit of reading current scientific papers or magazines. Developed by practice directed through teacher.

7. A realization of the important rôle physics plays in all forms of engineering.
   (a) The hydraulic engineer must have a knowledge of pressure
   (b) The mechanical engineer needs a knowledge of strength of materials
   (c) The chemical engineer must understand laws of gases.

8. A realization that physics has in very many ways contributed toward human comfort.
   (a) The phonograph and radio are physical inventions.
   (b) The steam engine and airplane are physical inventions.
   (c) The telephone and dynamo are physical inventions.

Complex 4

The Common Welfare

This complex has been included not because of the quantity of contributions that physics has to make to it, but rather by reason of the significance of the contributions and the fact that schoolmen everywhere are recognizing now as never before the necessity for building up a group consciousness.

"While engineering is reducing the natural barriers that have held peoples apart, while railroads and radios are . . . making the world smaller, the opposite

tendency prevails in politics and the artificial barriers of national boundaries, trade walls, divergent speech and hostile attitude are being erected and resurrected. It is an era of secession, separation, segregation . . . Race prejudices are encouraged and systematically cultivated. Sectarian distinctions are being emphasized."[6]

The outcome, a regard for the common welfare, appears in Dr. Yocum's Specifications for a Democracy; and because these specifications were checked for their validity by a group of one hundred distinguished Americans,[7] it is safe to assume the outcome to be an accepted purpose. "Essential Elements", as used, includes all three classes of elements described on page 36. Only experimentation can determine which or how many of the elements are required.

The Common Welfare Complex

Essential Elements:

1. A realization that the community is continually growing to be developed through experiences wherein the unifying influence of physical inventions is emphasized: steam power, telephone, telegraph, radio.
2. An attitude of faith in the expert

The American public must put faith in faithful experts. In physics we can center confidence in scientists of past and present. We do not have time or occasion in this life to verify all principles of physics. We must place faith in the testimony of the majority of physicists until their theories are attacked and successfully disproved in a fair trial.

3. Sense of responsibility for the group

Class methods in physics may be so developed as to create a sense of responsibility for the group in each pupil. A sense of cooperation should be present.

4. An attitude of love toward the common welfare

Developed through practice in liking the group sufficiently well to contribute toward its welfare. The socialized recitation in spirit at least will aid in developing such an attitude.

Complex 5

A realization of the relation of physics to the home

One of the distinctions between civilized man and savage is

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[6] Slosson, E. E. *op. cit.*, p. 32.

[7] Report of the committee on the Teaching of Democracy, a reprint of section of Vol. 61 of *Addresses and Proceedings of N. E. A.*, 1923, p. 5.

that the savage lacks perspective. There are gaps, very many gaps in his system of knowledge. His experiences lack organization. And from this ack of organization arises much of the fear, the ignorance and the superstition still present in the world. Not so long ago there was heard all around the world from a broadcasting station in the west an exposition seeking to prove that the earth is flat.[8] There is a great need for making an organized whole of one's environment instead of a hodgepodge of disjointed parts. The analysis of the two following complexes is an attempt to simplify an understanding of one's environment in so far as home life is influenced by physical principles.

. Table 1, page 28, shows very clearly the prevalence of these outcomes among accepted purposes. The last three questionnaire investigations reported, 11, 12, and 13, return these objectives as first in importance. Every element suggested herein can receive a contribution from physics teaching in the form indicated directly under each element. "Essential elements", as used, includes all three classes of elements described on page 36. Only experimentation can determine which or how many of the elements are required.

A realization of the relation of physics to the home

Essential Realizations:

1. Realization of the presence of the principle of expansion of gases, metals, and liquids on heating in
   - (a) The thermometer
   - (b) Steam heating of houses
   - (c) The thermostat
   - (d) Compensated pendulum
   - (e) Raising of bread
   - (f) Necessity for tuning a piano
2. Realization of the presence of the principle of evaporation in
   - (a) An artificial ice plant
   - (b) The maintaining of proper humidity in a home
   - (c) The double boiler

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[8] Slosson, E. E. *op. cit.*, p. 33.

(d) The drying of clothes on a windy day more rapidly than on a calm day.

3. Realization of the presence of the fact that water expands when it freezes in
   (a) Bursting water pipes
   (b) Preservation of fish life during winter

4. Realization of the difference between radiation, convection, and conduction as exemplified in
   (a) The uncomfortably hot handle of the teakettle
   (b) The warmth from the sun
   (c) Pipeless furnace put in the cellar rather than the attic.

5. Realization of the principle of specific heat involved in
   (a) A hot water bottle
   (b) A fireless cooker

6. Realization of the function of the pendulum in a clock

7. Realization of the principle of air pressure present in
   (a) the barometer
   (b) the fountain-pen filler
   (c) tall chimneys

8. Realization of the influence of unequal expansion in
   (a) The compensated pendulum
   (b) The breaking of glassware by heat
   (c) The opening of glass stoppers by application of heat

9. Realization of the way heat is measured in B. T. U.'s.
   Developed through demonstration of laboratory

10. Realization of the heat energy involved in foods
    Developed through experience in computing calorific values.

11. Realization of the principle of the energy nature of light present in the phenomena of
    (a) Lightning (relative speed of light and sound)
    (b) Mirrors (light travels in straight lines)
    (c) Color effects (light travels in different wave lengths)

12. Realization of the nature of the thermos bottle and the physical principles employed
    (a) Heat energy can not travel through a vacuum
    (b) Shining surfaces absorb less heat than dull surfaces

13. Realization of the energizing effect of an electric current passing through wire as shown in
    (a) The electric light and its incandescence
    (b) The electric grill and flat iron in the heat energy released

14. Realization of the principles of vibrating strings occurring in stringed musical instruments

(a) The vibration frequency varies inversely as the length of the vibrating string

(b) The vibrating frequency varies directly as the square root of the tension

(c) The vibrating frequency varies inversely as the square root of the weight per unit length of the string.

15. Realization of the principle of the motor involved in

(a) Electric fan and vacuum cleaner (made possible through Faraday's experiments)

(b) Electric light on large scale would not be possible without Faraday's invention of the dynamo.

16. Ability to read gas meter with an understanding of its working

17. Ability to read electric meter with an understanding of what it measures

18. Realization of the most economical position for heating pans over a bunsen burner.

Complex 6

A realization of the relation of physics to commerce and industry

Essential realizations:

1. Realization of the relation of the metric system to industry in foreign countries.

(a) Standard of measurement in all but England, Canada, U. S.

2. Realization of the many applications of the lever principle in industry

(a) The platform balance should be demonstrated

(b) Automobile foot brakes illustrate the principle

(c) The claw hammer should be demonstrated as a bent lever

(d) The shovel is a lever with weight near one end

3. Realization of the many phases of the principle of input equals output when output includes useful work plus wasted energy

(a) The automobile receives its energy from the gasoline which in turn received it from the sun. The energy put into the automobile is not all turned into work accomplished. Much of it is wasted in friction

(b) The locomotive, pile driver, jackscrew, all offer illustrations of the same principle

4. Realization of the important rôle friction plays in industry

Contributory elements: (a) Realization of the advantages of friction in making possible pulleys, automobiles, street-cars, railroad brakes, nails, screws, matches. Life would be impossible without friction. (b) Realization of the disadvantages of friction manifested in the principle that output equals input minus work lost through friction. (c) Realization of the ways of diminishing and of increasing friction.

5. Realization of the fact upon which the pressure in hydrants depends and of its application in industry.

(a) Practice in computing water pressure will enhance the realization

(b) Realization of the significance of pressure of liquids in the case of the submarine

(c) Realization of the tremendous mechanical advantages obtained in the hydraulic press

6. Realization of the influence of Archimedes' principle on the submarine, the dry dock, and all floating bodies.

7. Realization of the uses and principle of the hydrometer

(a) Storage batteries should be tested frequently as an important feature of their care

(b) Milk adulteration may often be detected by the hydrometer.

8. Realization of the significance of water turbines

(a) Practice in computing horse power developed by actual turbines now in operation will serve to strengthen the realization.

9. Realization of the dependence of dry farming on prevention of phenomenon of capillarity

(a) All water must be conserved. Capillarity aids evaporation.

10. Realization of the importance of fractional distillation to industry

(a) Petroleum distillation yields gasoline, kerosene, naphtha, benzine, vaseline, etc.

(b) Alcohol is obtained by distillation and water is purified by the same process.

11. Realization of the physical principles employed in gas engines

(a) The principles of expansion of gases

(b) The volatilization of liquids illustrated by gasoline

(c) The kindling temperature of substances illustrated by ignition devices

(d) The work principle illustrated by comparison of output and input.

12. Realization of the manifold uses of the permanent magnet in industry

(a) The compass is probably the oldest use of a permanent magnet

(b) Ammeters and voltmeters employ permanent magnets

(c) Telephone receivers are dependent upon permanent magnets

(d) Permanent magnets used in automobiles, motor cycles and airplanes, 200,000,000 in use in this country.

13. Realization of the theory of the lightning rod

Contributory elements: (a) Realization that electrons move through a conductor of electricity. (b) Realization that potential difference is attributable to concentration of electrons. (c) Realization that electrons have ability to jump a gap if there is sufficient concentration of them. (d) Realization

that this concentration is called voltage and that the number of electrons that move in a given time determines amperage.

14. Realization of the theory of the radio condenser as another illustration of the theoretical conception of electrical energy.

Contributory elements: (a) Realization that concentration of electrons on plates of the condenser finally determines the oscillatory motion of the electrons or electrical current. (b) Realization that the size of the plates and the distance of the plates from each other determine the capacity of the condenser for it determines the possibility for concentration of electrons.

15. Realization of the electrical theory utilized in electric lighting.

Contributory elements: (a) Realization that motion of electrons through a wire causes heat effects. (b) Realization that these heat effects will cause consumption of the wire by oxidation unless air is excluded. (c) Realization that the dynamo in the central plant serves to pile up protones on the positive wire and electrons on the negative wire.

16. Realization of the advantages of the barometer to industry

(a) Weather prognostications dependent upon its use

(b) Altitude measurements made from the barometer

17. Realization of the siphon action employed in aqueducts to carry water over hills.

(a) A study of the local water system with one or two large systems as has been made by Earl R. Glenn will contribute to this realization as well as to many other essential outcomes.

18. Realization of the carrying power of balloons and airoplanes with respective principles making balloons and airoplanes possible.

19. Realization of the nature of a gas meter and the physical principles upon which it depends.

(a) Demonstration or laboratory experimentation will strengthen the realization

(b) Realization of the kind of units that the meter measures

20. Realization of the significance of "factor of safety" in industry

Contributory elements: (a) Realization that steel used in industry must be tested for its physical properties. (b) Realization that much of engineering deals with computations of stress and strain that call for an understanding of physics. (c) Realization that physical properties are detected by use of the microscope, another physical invention.

21. Realization of the use of negative acceleration in determining the efficiency of brake linings.

22. Realization of the structure and principle of the automobile tire pressure gage.

23. Realization of the principle involved in the clock pendulum.

24. Realization of the applications of inertia to (a) the stopping of a car, (b) the hammer throw, (c) the bursting of revolving wheels, (d) the need of mud guards, (e) fly wheels, and (f) looping the loop tricks.

25. Realization of the significance of the expansion of substances with particular reference to bridges like the one over the Firth of Forth in Scotland, expansion joints in steam plants, quartz crucibles, and the sagging of wires.

(a) Practice in the solving of real problems in expansion will serve to strengthen this realization.

26. Realization of the sensitive thermoelectric detectors of radiant heat which locate hostile bombing airoplanes at night by detecting and getting the direction of the heat radiated by their engines.

27. Realization of the function of the voltmeter and ammeter.

(a) Used in research to control experimentation

(b) Used in industry to regulate conditions of manufacture

(c) Used in industry to test batteries for efficiency.

28. Realization of the composition and theory of the dry cell

Contributory elements: (a) Realization that the dry cell is useless when perfectly dry. (b) Realization of the theoretical similarity between a wet and a dry cell. (c) Realization of the structure of a dry cell developed through demonstration. (d) Realization that dry cells are used in very many different practical situations.

29. Realization of the usefulness of the electro magnet

(a) Buzzers and doorbells employ the electro magnet

(b) Electro magnets are capable of lifting tons of iron at one time.

30. Realization of the usefulness of a storage battery and of its proper care

Contributory elements: (a) Realization that the storage battery makes possible the lighting system of automobiles and the propelling force of electrically driven automobiles. (b) Realization that the storage battery requires care in its treatment to guarantee long life. (c) Realization of the structure of the storage battery developed through demonstration or laboratory experimentation.

31. Realization of the theory of the telegraph.

32. Realization of the significance of the fuse in an electric circuit developed through a consideration of the wiring system in homes.

33. Realization of the contribution of the motor and dynamo to modern commerce and industry along with an understanding of the physical facts which make them possible.

34. Realization of the structure and functioning of an ignition system found in a common type of automobile.

35. Realization of the applications of the principle of the transformer in (a) radio, (b) electric toys, (c) transmission of power.
36. Realization of the rôle of physical invention during the world war
(a) Sound-ranging during the world war was perfected to a point never before attempted
(b) Every branch of physical investigation was quickened by the war.
37. Realization of the use of the siren principle in every-day life.

Complex 7

"*The Spirit and Service of Science*"

In the introduction to his excellent book, entitled the "Spirit and Service of Science", Sir Richard Gregory has to say of the popular notion of the scientist:

"To the popular mind, a man of science is a callous necromancer who has cut himself off from communion with his fellows, and has thereby lost the throbbing and compassionate heart of a full life: he is a Faust who has not yet made a bargain with Mephistopheles, and is therefore without human interest. Scientific and humanistic studies are indeed supposed to be antipathetic, and to represent opposing qualities; so that it has become common to associate science with all that is cold and mechanistic in our being, and to believe that the development of the more spiritual parts of man's nature belongs essentially to other departments of intellectual activity."

Such a belief on the part of the populace is not productive of the kind of close cooperation between the scientific mind and the practical man which makes for progress and accomplishment. A certain amount of experimentation is necessary in social science: scientifically controlled experimentation is relatively unpractised in education. Science has in no field completed its contribution to human welfare; and it ought to be encouraged by an understanding cooperation with its agents. In another place, we have spoken of faith in the expert, a very necessary requisite for a democracy in the modern complexity of life. An attitude of respect for the spirit and service of science will make people more willing to put faith in the scientific expert. An attitude of respect for the spirit and service of science wil also assure a strengthening of controls necessary to the realization of many of the accepted objectives listed as a result

of the investigation of literature on objectives in the teaching of science.

A reason for intensive treatment of this outcome is its range and recurrence in the form of a strengthening essential in other complexes treated as revealed in the recapitulation on page 59. "Essential elements", as used, includes all three kinds of elements described on page 36. Only experimentation can determine which or how many of the elements are required.

An attitude of respect for the "spirit and service of science"

Essential Elements:

1. Realization of the contribution physics has made to social and individual welfare

Contributory elements: (a) Realization of the preponderance of physics knowledge and theory involved in the "seven wonders of the modern world", wireless telegraphy, the telephone, the airplane, radium, anaesthetics and antitoxins, spectrum analysis, and X-rays. (b) Realization of the revolutionary results that the modern experimental method of inquiry as championed by the physicist, Galileo, has produced in contrast with the meagre showing of nearly two thousand years of Aristotelian logic.

(1) Every person has the equivalent of some 20 slaves at his service in the form of mastered forces of nature.

(2) Living has been revolutionized in the last fifty years.

(c) Realization of the complexity of society made possible by an understanding of the laws of nature.

(1) Steam power has made our kind of government a possibility.

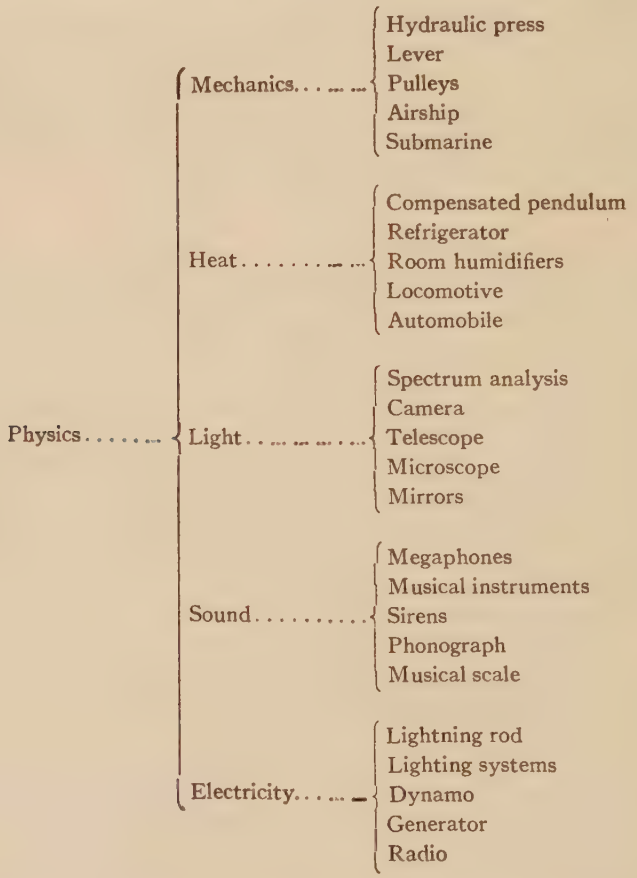
(2) Wireless telegraphy, the telephone, airoplane, radio, steam engine are all tending to break down natural barriers and make the world a community.

(3) Without the applications of the laws of the lever, the pulley, and other machines, modern society would be impossible.

(d) Realization of the relief to human pain and suffering achieved through radium and the X-ray. (e) Realization of the potential benefits yet to be earned by investigation of atomic energy. (f) Realization of the value of the telescope in helping the individual understand the vastness of the universe.

(1) The naked eye sees less than three thousand stars on most favorable occasions: the perfected eye of the telescope locates 100,000,000 stars. "The heavens declare the glory of God and the earth showeth his handywork."

(g) A vocabulary control suggesting location in the following manner:



2. Realization of the disinterested motive of pioneers in science

(a) A study of the significant features of the life of men like Clerk Maxwell, Hertz, Faraday, the Curies, Newton, Ampere, Gauss, Oersted, Lavoisier will emphasize the fact that they worked because of an interest in scientific discovery, not for the tinsel of personal reward.

3. Realization that commercial manifestations of scientific research depend upon what was in their time thought to be relatively insignificant discoveries.

(a) Fifty years elapsed before Faraday's experiment with a magnet and

coil was employed in a practical way. Now the dynamo and lighting systems everywhere proclaim its significance.

(b) Newton's study of the decomposition of light by means of a glass prism has lead inevitably to the wonderful accomplishments of spectrum analysis.

(c) It was 33 years from the first voltaic pile to its application in a very crude magneto-electric telegraph.

4. A realization that the last fifty years has seen more material progress than that achieved before in the whole history of man.

(a) An enumeration of discoveries in physics during last fifty years will strengthen the realization.

5. An attitude of admiration of the scientist's disinterestedness.

6. Attitude of admiration for the wonders of physical universe.

Inclusive Assembling of Contributing Elements According to their Kind and According to the Frequency of their Recurrence in the Analysis.

Realizations

Realization of the universality of cause and effect—C. 1; [C. refers to complex].

Realization of the difference between the scientific method and the method of argument—C. 1;

Realization of the influence of prejudice—C. 1.

Realization of the vast change since 1600 attributed to the scientific method —C. I.

Realization of the importance of the scientific habit of thinking—C. 1.

Realization that scientific judgments are suspended judgments— C.1.

Realization of the present inadequacy of science in interpreting life— C. 1; C. 2.

Realization of the greater appreciation and enjoyment of living that comes through an interpreting of life's values in a scientific way—C. 1.

Realization of the power of perseverance.—C. 1.

Realization of the inexorability of natural law—C. 2.

Realization of the mysteries of the atom pointing the way to the unfolding of knowledge more bewildering than the tenets of faith have asked of man— C. 2.

Realization of the significance of the conservation of energy principle when applied to the destiny of the mind—C. 2.

Realization that many of the changes about us are physical—C. 3.

Realization of the important rôle physics plays in human relationships with all of its subsidiary realizations—C. 3; C. 3; C. 7; C. 3.

Realization of the relation of physics to the home with all of its subsidiary realizations.—C. 5.

Realization that the community is continually growing—C. 4.

Realization of the relation of physics to commerce and industry with all of its subsidiary realizations—C. 6.

Attitudes

Attitude of wonder—C. 1.
Attitude of distrust in snap judgment—C. 1.
Attitude, religious—C. 1; C. 2.
Attitude of respect for men of faith who try to explain mysteries of nature—C. 2.
Attitude of faith in the expert—C. 4.
Attitude of love for the common welfare—C. 4.
Attitude of admiration for the disinterestedness of the scientist—C. 7.
Attitude of admiration for wonders of physical universe—C. 7.

Sensings

Sense of the beautiful in natural effects—C. 1.
Sense of pride in achievement—C. 2.
Sense of precision—C. 2.
Sense of confidence—C. 2.
Sense of humility—C. 2.
Sense of the immensity of the universe as determined by physical calculation—C. 2.
Sense of pleasure in study of physical phenomena—C. 3.
Sense of curiosity developed and stimulated by questions—C. 3.
Sense of respect for experimentation—C. 3.
Sense of responsibility for the group—C. 4.

Standards

Standard of verifying everything important enough to warrant verification—C. 1.
Standard of clear expression—C. 2.
Standard, knowledge of physics—C. 2.
Standard of right living—C. 2.
Standard of toleration—C. 2.
Standard of truthfulness—C. 2.
Standard of self-sacrifice—C. 2.
Standard of self-realization—C. 2.

Habits

Habit of seeking only the truth—C. 1.
Habit of selective observation—C. 1.
Habit of neatness, carefulness, accuracy—C. 1.
Habit of making physics a hobby—C. 3.
Habit of reading scientific journals—C. 3.

Abilities

Ability to read gas meter—C. 5.

Ability to read electric meter—C. 5.

Memorized general ideas

Memorized general idea "Verification wherever consequences harmful to self or to others may result from error".—C. 1.

Miscellany of memorized general ideas (principles of physics)—C. 1; C. 3.

Vocabularies

A memorized vocabulary sequence suggestive of manner of procedure in the scientific method and practice in its use—C. 1.

Interconnection insured by memorized vocabulary—C. 7.

Memorized vocabulary to insure transfer—C. 1.

VI

How Establish Realizations; through Immediate or Assembled Situations? Laboratory vs. Demonstration

Little has been attempted by way of testing scientifically the relative efficiency of various methods in accomplishing pre-determined outcomes. The difficulties are legion: the rewards, meager indeed. Though argument and opinion are easy to find, scientific experimentation in education is in its infancy. Without scientific experimentation of the kind exemplified in the following investigation, the analysis of Chapter 5 can not reach its highest degree of usefulness. Ultimately every step of the analysis must be checked by practical experimentation and measurement. Questions involving the factors in distinguishing method and the inclusion or exclusion of specific elements under any outcome in order to strengthen or counteract the outcome itself, as well as problems involving the evaluating of complexes must all be answered finally by scientifically controlled experimentation. It is to exemplify the kind of experimentation necessary in every phase of the educational process that this investigation has been included in the thesis.

In 1880 there were said to be four schools in the country giving a full year's work in physics with laboratory work by the pupils.[1] Today individual laboratory work is a most important phase of the teaching of physics in the high school. A combination of circumstances has made possible a very rapid development of high-school laboratories in this country; and no little credit for the ascendancy of the laboratory should be given to men like David Starr Jordan who during his vigorous fighting for the universal use of the laboratory method had the following to say:

"There is a charm about real knowledge which every student feels. The magnet attracts iron, to be sure, to the student who has learned the fact from

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[1] *Bureau of Education Bulletin 6*, 1880, p. 10.

the book, but the fact is real only to the student who has felt it pull. It is more than this—it is enchanting to the student who has discovered the fact for himself. To read a statement of the fact gives knowledge, more or less complete, as the book is accurate or the memory is retentive. To verify the fact gives training: to discover it gives inspiration. Training and inspiration, not the facts themselves, are the justification of science teaching."[2]

Another writer speaks of the

"difference in the clearness and vividness of the precepts we get from laboratory work as contrasted with those we obtain from book study."[3]

As a general thing, the laboratory method in one form or another has come to be an accepted practice in educational circles.

Occasionally, however, one hears a dissenting voice. In Parker's "Methods of Teaching n the High School", there appears the statement,

"In many cases, where observation and reflective thinking about real situations are more important than acquiring skill in manipulation, the demonstration method is much superior to individual work. The time that is used by individual pupils in setting up apparatus could often be used to much better advantage in reflective thought based on observation."[4]

E. M. Jones of Adrian College writes:

"The writer is of the opinion that some time in our future educational journeyings we will restrict the use of laboratories to those students who have advanced rather far toward their degree in college and have shown a distinct ability to really profit by laboratory manipulations."[5]

And then there is the testimony of Dr. Thorndike to the effect that

"Washing bottles, connecting electric wires and putting away test tubes, though doubtless useful tasks in connection with scientific housewifery, are not magical sources of intellectual growth."[6]

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[2] *School Science and Mathematics*, 1919, p. 209.
[3] Harvey, N. A. The Psychology of the Laboratory. *School Science and Mathematics*, 1922, p. 535.
[4] Parker, S. C. *Methods of Teaching in the High School*, p. 457.
[5] Laboratory vs. Recitation, *School Science and Mathematics*, 1923, p. 749.
[6] Thorndike, E. L. *Education*, p. 178.

Those who are thinking about problems of educational method are not unanimous in their endorsement of the laboratory method as an efficient means of reaching the most desirable educational objectives of high-school instruction. Dr. Yocum of the University of Pennsylvania has long since pointed out the relatively modern tendency of neglecting the potency of the revived or assembled experience to exalt the power of immediate experience. Laboratories, of course, find their only justification in the supposedly greater efficacy of immediate experiences in producing desirable outcomes. It remains for adequate experimentation to determine the relative worth of immediate experiences as contrasted with assembled experiences for the establishment of desirable outcomes.

There have been several noteworthy experiments conducted with the purpose of testing the relative efficiency of the laboratory method and the demonstration method in the teaching of physics. The experiment conducted by William H. Wiley[7] and that of H. A. Cunningham[8] are both valuable indices of the probable solution of the problem. The investigation of George W. Hunter contrasts the effect of three possible methods —the "developmental" method, the text-book method, and the lecture method.[9] J. L. Cooprider, after experimenting with the laboratory method in contrast with the demonstration method, concludes that to meet immediate needs the demonstration work is better adapted than is individual laboratory work, but that laboratory work is superior in providing for retention of the thing learned.[10] E. W. Kiebler and Clifford Woody working together in Hillsdale High School found that the results of the demonstration method were as good, if not superior, in all three types of tests given—tests for immediate knowledge, tests for permanent knowledge, and tests for knowledge of how to apply principles of technique in solving new problems.[11]

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[7] Results published in the *Journal of Educational Psychology*, Vol. 9, pp. 181–198.

[8] Results published in *Proceedings of Illinois Academy of Science*, 1920.

[9] Results published in *School Science and Mathematics*, 1921, p. 875.

[10] Laboratory Methods in High School Science, *School Science and Mathematics*, June 1923.

[11] Results published in *Journal of Educational Research*, Vol. 7, p. 50, 1923.

As a matter of fact, in every experiment reviewed by the writer, results favored slightly the efficacy of the demonstration method for immediate needs of the pupils: there are, however, occasional indications of the superiority of the laboratory method in tests that were given after a period of time had elapsed between the teaching and the testing.

The investigations themselves, however, are not without their weaknesses in matters of procedure. Two counts indict all of them. In the first place, no basal test was given. Just how many of the facts were present in the minds of the pupils before the experimental factor was added, nobody is in a position to say. Repeaters, of course, were being subjected to the laboratory method at least twice,—the effects of two administrations of the laboratory method were being compared with the effects of one administration of the demonstration method. Then again there may have been a certain carry-over from previous experiences which would entirely vitiate the results of experimentation. There is the chance that nothing of the kind happened, but as experimenters it is our duty to eliminate chance as far as possible. With all of the precaution humanly possible there will still be variable factors that will render results more or less inexact.

In the second place, there is an unfortunate confidence in the competency of a median of too few measures adequately to describe the central tendency. The present investigation will deal with groups larger than any reported in the experiments described above, and yet the author does not presume to make any sweeping conclusion on the strength of the results. Only an indication of a probability can be discovered from the use of small numbers of pupils. Rugg in his "Statistical Methods Applied to Education" describes precisely the error of which these experiments are culpable:

"The second definite problem that has to be clear to the student who wishes to grasp sound methods of 'averaging' takes account, first, of the differences in proper methods to use in the case of small numbers of measures as opposed to large numbers. With small numbers of measures (perhaps 10 to 20 or 30) and anything but a very symmetrical distribution over a very short range,

the wisdom of using any average to typify the measures is questionable. Rather than do this, the whole distribution should be presented and discussed in detail."[12]

In the investigations reviewed, the measures were small, usually less than thirty, and the only means of comparison available to the reader were the medians.

Perfection of measurement in anthropology, on the other hand, cannot be expected. If the medical doctor had suspended his practicing until scientific experimentation had proved beyond all question of a doubt the relative efficacy of certain drugs in specific ailments by exact measurement, medicine would not be contributing to man's welfare as it is today. Undaunted by the absence of means of measuring exactly and minutely, schoolmen must push forward with the crude devices available and content themselves with indications of the truth where only indications are available.

As indications of the truth, the experiments reviewed are invaluable. By reason of the two counts cited above, they are not conclusive proof: they were probably never intended so by their authors. They are contributions toward the scientific solution of a very important problem in education.

It will be the province of this experiment to test by means of a series of classroom experiments the relative value of a developmental-demonstration method and of a laboratory method with reference to their efficiency in building up certa n outcomes in the minds of pupils and with reference to permanency of realization once established. The outcomes tested for are all of them realizations, one of the elements found under "impression control". Skills and technique form no part of this experiment. The investigation is concerned simply with the more efficient method of establishing realizations and with the permanency of realizations once established.

The pupils chosen for the experiment were boys and girls then in the high school in which the writer is serving as principal. They were chosen because of their accessibility and because of the large number in the h gh school taking physics. In a similar

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[12] Rugg, H. O. *Statistical Methods Applied to Education*, p. 108.

experiment conducted one year before this one, the writer was seriously handicapped by reason of small groups vitiating measurements of central tendencies. The general character of the student body is exceptionlly good as being representative of the kind of boys and girls found in a high school wherein only academic subjects and business courses are taught. The physics classes hold unselected groups in that everybody not in the business course takes physics in the third year—a condition that tends automatically to produce equivalent groups.

Preliminary tests, nevertheless, disclosed the necessity for deliberate balancing by the elimination of a few atypical pupils. The preliminary test found below was designed to measure the specific ability of each pupil, involved in the investigation, in forming realizations of the kind tested for later in the experiment. It was given immediately after the subject of the mechanics of fluids had been completed in class. The questions were of the true-false type and each one was weighted with a score of five. The test follows:

Preliminary Test Given to Balance Groups

If the statement is correct, place a plus sign after it; if incorrect, place a minus sign after it.

1. If a body weighs less than the displaced liquid, it will float.
2. At a given depth in a liquid, the downward pressure is always greater than the upward pressure.
3. The downward pressure at the bottom of a vessel depends upon the shape of the vessel.
4. The buoyant force exerted by a liquid is exactly equal to the weight of the displaced liquid.
5. When a body is immersed in a liquid, it is buoyed up by a force equal to the weight of the body.
6. A floating body must displace its own weight of the liquid in which it floats.
7. All gases are liquids.
8. Pressure is force per unit area.
9. Pressure exerted on any part of a fluid inclosed in a vessel is transmitted only in one direction.

10. In any liquid with a free surface, the pressure at any depth is proportional both to the depth and the density of the liquid.

11. In any liquid with a free surface, the pressure at any given point does not depend upon the amount of the liquid in the vessel.

12. The specific gravity of a substance is its weight per unit volume.

13. Disregarding the compressibility of water, the buoyancy on a body one mile below the surface of the ocean is greater than one-half mile below.

14. In the C. G. S. system, specific gravity and density are numerically the same.

15. One cubic centimeter of any liquid weighs one gram.

16. A hydrometer will sink until the weight of the displaced liquid equals the weight of the hydrometer.

17. An ocean steamer draws less water when it enters fresh water.

18. The pressure against a dam that backs up the water for a mile is greater than that which backs up the water for a half mile.

19. There is no difference between force and pressure.

20. It is impossible to find the specific gravity of a solid lighter than water.

The first tabulation in Table III, page 77, and in Table IV, page 78, reveals the scores made in the preliminary tests by each of the pupils not atypical. A pupil is regarded as atypical who was not on hand to take all of the tests or who by reason of low mentality represented an abnormality in a group or who as a repeater did not represent the typical pupil. The atypical pupils were not listed in the scoring. Table II, below, represents the distribution of the scores made in the preliminary tests by the pupils of each group. The median of the first group, 80.28, must be compared with the median of the second group, 72.97. The arithmetic mean of the first group, 71.84, must be compared with the arithmetic mean of the second group, 70.71. Both measures of central tendency indicate that the second group is but slightly inferior in the effectiveness with which desirable realizations are built up.

TABLE II

DISTRIBUTION OF SCORES IN PRELIMINARY TEST WITH MEDIANS AND MEANS OF EACH GROUP

GROUP 1		GROUP 2	
SCORE	FREQUENCY	SCORE	FREQUENCY
95	1	95	2
90	6	90	8
85	9	85	3
80	9	80	9
75	3	75	3
70	4	70	16
65	2	65	7
60	3	60	4
55	6	55	3
50	2	50	3
45	1	45	4
40	1	40	0
35	2	35	1
Median	80.28	Median	72.97
Mean	71.84	Mean	70.71

It is advisable when possible to use preliminary tests designed to test for the specific trait examined later in the experiment. The preliminary test reported above was designed by the writer in order to test the relative ease with which realizations were established in the minds of the pupils on the assumption that the number of questions answered correctly would be an indication of the number of correct realizations that had been built up in each individual. A valuable check on a test of such a nature is a standardized intelligence test. In this experiment the Otis Group Intelligence Test (Advanced Form) was employed. The first column in Table VII, page 83, and Table VIII, page 84, represents the scores made by each pupil, not atypical, in the Otis Group Intelligence Test. Table IIa, below, represents the distribution of the scores made in the Otis Test by the pupils of each group. The median of the first group, 142.5, must be compared with the median of the second group, 139.6. The arithmetic mean of the first group, 144.2, must be compared with the arithmetic mean of the second group, 142.7. Both measures of central tendency support the evidence of the other preliminary test to the effect that the second group is just slightly weaker than the first group.

TABLE IIA

DISTRIBUTION OF SCORES IN THE OTIS GROUP INTELLIGENCE TEST WITH MEDIANS AND MEANS OF EACH GROUP

GROUP 1		GROUP 2	
SCORE	FREQUENCY	SCORE	FREQUENCY
195–204.99	1		
185–194.99	3	185–194.99	1
175–184.99	2	175–184.99	5
165–174.99	4	165–174.99	4
155–164.99	4	155–164.99	9
145–154.99	6	145–154.99	3
135–144.99	10	135–144.99	12
125–134.99	8	125–134.99	10
115–124.99	1	115–124.99	8
105–114.99	2	105–114.99	2
95–104.99	3	95–.04.99	2
85– 94.99	1	85– 94.99	1
Median.....	142.5	Median.....	139.6
Mean (arithmetic).....	144.2	Mean (arithmetic).....	142.7

For the purpose of the investigation, the groups—with the atypical cases excluded as they are—may be considered as balanced. Whatever slight advantage may have been found in difference in inherent ability in the two groups was given to the laboratory method; for Group 2, the slightly weaker group, worked under the demonstration method in two of the three possible instances. In the last case, Group 2 worked under the laboratory method.

The teacher chosen to carry out the procedure of the experiment is a man who has taught physics about three years (using during that time both laboratory and demonstration method); one who has several years ago been engaged in research work of a chemical nature. He was at the time of the experiment the instructor of the physics classes in question and had been about two months before the experiment was conducted. He seemed particularly desirable as the conductor of the experiment by reason of his scientific training, his unbiased attitude, and his accustomed presence in the classes affected.

As has been suggested above, the method of experimentation employed was that of equivalent groups, and of rotating groups. With one group (Group I) the laboratory method was used in the first two trials: with the other group (Group 2), the developmental-demonstration method was used. In the last trial,

however, Group I worked under the demonstration method and Group 2 worked under the laboratory method.

The procedure involved in the laboratory method was that of the usual practice. Mimeographed sheets, submitted in the appendix, were given to the pupils the day before the experiment with the task of answering the introductory problems as their assignment for the next day. Those who had not answered the questions assigned were not allowed to perform the experiment. The mimeographed sheets (found in the appendix) furnished all the directions available to the group. The pupils were assisted in their work by the instructor who walked from one desk to the other checking procedure and results and answering questions that were asked. The class was conducted in a laboratory equipped with enough apparatus to allow the pupils to work in groups of threes. During the last ten minutes of the fifty-five minute period allotted to the experiment, the final test was given.

In the developmental[13]-demonstration method, the instructor sought to introduce the lesson with a thought question taken from the introductory questions found on each mimeographed sheet. The class was conducted in a classroom in which the movable seats were so arranged that the demonstration desk at the front of the room was in plain view. The demonstration was at no time formal in any way: it was employed as a means of illustrating the questions under consideration. The topic was "developed" by means of the demonstration. The instructor performed all of the manipulation while he guided the discussion and stimulated thinking with thought questions. During the last ten minutes of the fifty-five-minute period, the final test was given in precisely the same manner as in the laboratory group.

It should be explained that the so-called laboratory group is really composed of two classes and the demonstration group of three classes. For the first two experiments, this condition holds true: in the last experiment, when the groups are rotated as a check on the balancing, the demonstration group is composed of two classes and the laboratory group of three classes.

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[13] McMurry, F. M. *The Method of the Recitation*, p. 121.

In the first two experiments the laboratory classes were held during the first and second periods of the day and the demonstration groups during the fifth, sixth, and seventh periods of the day. In the third experiment the conditions were exactly reversed.

A trial experiment was run about one year before the experiment reported. The preliminary tests were given March 4, 1926. A basal test was given March 18, 1926. The experimental factors were employed on March 23, 24, and 25th of the same year and the final tests were given on the same days. In November 1926, the same final tests were given again in order to test for the permanency of the realizations once established. No time for comment was allowed in the November examination. The questions were asked and answered on mimeographed sheets, specimens of which are found in the appendix.

The basal test follows:

1. What is meant by the resultant of two or more forces?
2. How is the equivalent of a force determined?
3. Make a drawing to show that you understand what is meant by a parallelogram of forces.
4. How would you load a meter stick?
5. Define "center of gravity".
6. Make a drawing of a lever and show how moments are computed.
7. Define "period" of a pendulum.
8. Upon what one factor does the rate of vibration of a pendulum depend?
9. Define "single vibration" of a pendulum.
10. How is the magnitude of forces measured?

As was to be expected from a consideration of the working conditions, the basal test showed a negligible trace of the realizations in questions. Only two pupils answered any of the questions correctly, and they were excluded from the investigation because of the fact that they were repeaters. In their case there was present a certain carry-over of realizations from the previous semester's work. The results of the basal test show conclusively that the realizations tested for later in the investigation were not present at the beginning of the investigation.

This kind of carry-over or transfer of realizations from one experiment to the other is guarded against in the fact that the experiments themselves deal with widely different principles in physics.

The instructions for the first experiment are found in the appendix. The final test for Experiment 1 follows:

1. Does the weight of the bob make a difference in the time of vibration?
2. Does the kind of substance make a difference in the time of vibration?
3. Does the length of the string make a difference in the time of vibration?
4. Does the size of the arc make a difference in the time of vibration?
5. Did we consider in any way the weight of the thread?
6. If we wished fewer vibrations per minute should we lengthen or shorten the thread?
7. Does it take a pendulum longer to swing through a long arc than through a small one?
8. If you wished the pendulum of a clock to make fewer vibrations per minute, what should you do to it?
9. Upon what factor does the rate of vibration of a pendulum depend?
10. What was the object of this experiment?
11. Do you feel that you thoroughly understand this experiment?

The purpose of Experiment 1 is to give to the pupil an understanding of the fact that the time of vibration of a pendulum, or the number of times a pendulum vibrates per minute, depends upon the length of the pendulum and only upon the length of the pendulum, and that the longer the pendulum, the less frequently it vibrates. Involved in the understanding are three major realizations:

1. A realization that the weight of the bob, the kind of substance in the bob, the size of the arc, and the weight of the thread are of no consequence in determining the number of vibrations per minute.
2. A realization that the length of the string determines the number of vibrations per minute.
3. A realization that lengthening the string will decrease the number of vibrations per minute.

Questions 1, 2, 3, 4, 5, and 7 are designed to test for the presence of the first realization: questions 9 and 10 for the second realization: and questions 6 and 8 test for the third realization. Ques-

tion 11 is a subjective measurement of the clearness with which the subject-matter was presented.

Instructions for Experiment 2 are found in the appendix. The purpose of Experiment 2 is to give to the pupil an understanding of the manner in which the weight of a body is considered to be concentrated at the center of gravity and of how the force acting at the center of gravity may be measured. Involved in the understanding are four major realizations:

1. A realization that the weight of the loaded meter stick is considered to be concentrated at the center of gravity.
2. A realization that the substance of the lever or fulcrum is not a determining factor in the experiment.
3. A realization that the center of gravity of the loaded meter stick was a fixed point and that it was determined by balancing the loaded meter stick.
4. A realization that the final balancing point of the lever is determining in finding the force acting at the center of gravity.

The final test for Experiment 2 follows:

1. How was the meter stick loaded?
2. Must the lever used in this experiment be made of wood?
3. Is it necessary to know the weight of the loaded meter stick?
4. Is it necessary to know the weight of the meter stick without the load?
5. Is it necessary to know at just what point the fulcrum is loaded?
6. What force acts at the center of gravity, the 200-gram weight or the weight of the loaded meter stick itself?
7. Would calculated results be different if the fulcrum were made of aluminum?
8. At what spot do we consider the weight of the loaded meter stick to be acting?
9. How was the center of gravity of the loaded meter stick located?
10. Does the center of gravity of the loaded meter stick change from one minute to the next?
11. Do you feel that you thoroughly understand this experiment?

Questions 1, 3, 4, 6, and 8 test for the first realization mentioned above: questions 2 and 7 for the second: questions 9 and 10 for the third: and question 5 for the fourth realization.

Instructions for Experiment 3 are also found in the appendix. The purpose of Experiment 3 is to give to the pupil an under-

standing of the relation between three forces acting on a body at a point in such a way that they are in equilibrium. Involved in such an understanding are three major realizations:

1. A realization of the relation between the resultant and the equilibrant.
2. A realization that the balances employed measured the magnitude of the forces in grams.
3. A realization of the function of the parallelogram in determining the resultant of two forces.

The final test for Experiment 3 follows:

1. May any one of the forces in equilibrium be taken as the equilibrant?
2. Should the resultant and the equilibrant be equal in magnitude?
3. How is the magnitude of the forces measured? (How found?)
4. How is the equilibrant measured? (How found?)
5. How is the resultant determined? (How found?)
6. Is it necessary to draw a parallelogram in order to determine the magnitude of the three forces?
7. Is it necessary to draw a parallelogram in order to determine the magnitude of the equilibrant?
8. Did the markings on the balance represent pounds, grams, or centimeters?
9. Must the forces in all three directions be equal in order to produce equilibrium?
10. Is it necessary to measure the length of the diagonal of the parallelogram at any time during the experiment?
11. Do you feel that you thoroughly understand this experiment?

Questions 1, 2 and 9 test for the first realization mentioned above; questions 3, 4 and 5 test for the second; and questions 6, 7 and 10 test for the third realization. Question 11 serves the same purpose as in Experiment 1 and in Experiment 2.

The only variation during the procedure that approached the proportions of a disturbing factor was the shortening of the fifth period about ten minutes on all three days. For the administering of the demonstration method, the shorter period had no effect whatever: in every instance the work when conducted under the demonstration method was completed ten minutes before the close of the normal fifty-five-minute period. The one laboratory experiment employed during the short fifth period suffered slightly, however, for a lack of sufficient time to

conduct the class without some speeding up by the instructor. The work was completed on time, nevertheless, and the final test answered before the class was dismissed.

From Table III, page 77, and Table IV, page 78, it will be seen that Group 1 was composed of forty-nine pupils and Group 2 was composed of sixty-three pupils. Results of the preliminary test as represented in Table II and IIa, page 69 and page 70, indicate that the groups were approximately equivalent (equivalency measured by means and medians) in respect to the ability of reacting to influences that tend to establish realizations as measured by the use of these realizations in answering questions. Any disparity in equivalency of groups was checked during the investigation by reversing the groups—the one that was first tested with the laboratory method was finally tested with the demonstration method, and *vice versa*. As a matter of fact this form of checking materially strengthens the conclusions of the experiment, for the slightly weaker group (Table II and IIa) in two of the three possible instances was subjected to the method that in all but one case gave evidence of being more efficient in doing what it was supposed to do. If the demonstration method enables the weaker group to surpass the stronger group working under the laboratory method, then we have reason for believing that the demonstration method is more profitable.

Table V, page 80, shows the distribution of scores in the final tests given for immediate establishment of realizations and allows comparisons between accomplishments of Group 1 and Group 2 under the effect of the demonstration method and under the effect of the laboratory method. In every instance both the arithmetic mean and the median of scores made in each experiment give the advantage to the demonstration method. Each question is given a score of 1.

In the first experiment, Group 1 worked under the laboratory method and Group 2, the slightly weaker group, worked under the demonstration method. The mean of the scores of Group 2 is greater than the mean of the scores of Group 1 by 1.59. The median of the scores of Group 2 is greater than the median

TABLE III

RESULTS OF PRELIMINARY AND FINAL TESTS

GROUP 1

PUPIL NO.	PRE EXAM.	1ST EXP. LAB.		2ND EXP. LAB.		3RD EXP. DEM.	
		SCORE	REACTION*	SCORE	REACTION*	SCORE	REACTION*
1	75	8	No	5	No	5	No
2	80	8	Yes	8	No	7	Yes
3	90	7	No	8	No	6	Yes
4	90	7	No	7	No	6	No
5	90	7	No	8	Yes	9	Yes
6	85	6	No	10	No	4	No
7	90	4	Yes	9	Yes	6	No
8	80	7	Yes	8	No	7	Yes
9	55	7	No	8	No	8	No
10	50	3	Yes	9	No	7	No
11	85	4	Yes	7	No	6	No
12	80	7	Yes	8	No	4	No
13	85	5	Yes	8	No	5	No
14	90	4	Yes	8	No	7	No
15	50	3	No	9	No	5	No
16	75	5	Yes	10	No	5	Yes
17	80	5	No	8	No	9	No
18	45	8	Yes	8	No	3	No
19	35	5	No	6	No	3	Yes
20	35	9	Yes	7	No	4	No
21	65	8	No	5	No	6	No
22	70	9	No	7	No	6	No
23	70	9	Yes	7	No	7	No
24	55	8	No	8	No	7	No
25	55	6	Yes	5	No	3	No
26	70	8	Yes	9	No	6	No
27	55	3	Yes	6	No	4	No
28	55	7	No	8	No	4	No
29	80	8	Yes	9	No	9	Yes
30	40	5	No	7	No	6	No
31	65	7	Yes	9	No	7	No
32	55	8	No	7	No	7	No
33	85	9	Yes	8	No	7	No
34	90	8	No	10	No	6	No
35	60	6	No	7	Yes	6	No
36	85	7	No	8	Yes	8	No
37	85	7	Yes	7	No	5	No
38	75	9	No	9	No	7	No
39	85	7	No	10	No	5	No
40	80	9	No	8	No	5	No
41	80	4	Yes	9	No	4	No
42	85	8	No	10	No	5	No
43	85	9	No	9	No	4	Yes
44	95	6	No	10	No	5	No
45	70	3	Yes	8	No	4	No
46	60	10	Yes	9	No	6	No
47	60	5	Yes	8	No	5	No
48	80	9	Yes	10	No	5	No
49	80	7	Yes	8	No	4	No
Mean	71.84	6.69	Yes 25	8.04	Yes 4	5.63	Yes 7
Median	80.28	7.54	No 24	8.58	No 45	6.14	No 42

* Refers to answers to question 11 of final tests.

TABLE IV

RESULTS OF PRELIMINARY AND FINAL TESTS

GROUP 2

PUPIL NO.	PRE EXAM.	1ST EXP. DEM.		2ND EXP. DEM.		3RD EXP. LAB.	
		SCORE	REACTION*	SCORE	REACTION*	SCORE	REACTION*
1	70	8	Yes	10	No	7	No
2	80	9	Yes	10	No	3	No
3	90	8	Yes	10	No	8	Yes
4	70	7	Yes	8	No	5	No
5	95	8	No	7	Yes	2	Yes
6	45	9	Yes	8	No	5	No
7	60	7	Yes	8	No	4	No
8	85	5	Yes	9	Yes	5	No
9	80	10	Yes	8	Yes	6	No
10	50	10	Yes	8	No	7	No
11	65	8	Yes	8	No	6	No
12	85	9	Yes	9	No	6	No
13	55	7	Yes	9	No	5	No
14	80	7	No	8	Yes	3	No
15	95	10	Yes	9	No	4	No
16	90	10	Yes	7	No	7	No
17	90	10	No	8	No	8	Yes
18	70	10	Yes	9	No	6	Yes
19	60	10	Yes	8	No	6	No
20	50	7	Yes	7	No	4	No
21	35	9	No	9	Yes	5	No
22	70	6	No	8	No	2	No
23	90	10	Yes	10	No	4	No
24	90	8	Yes	9	Yes	5	No
25	90	9	Yes	8	No	4	No
26	70	10	Yes	8	No	6	No
27	70	9	Yes	10	No	5	No
28	60	9	Yes	10	No	6	No
29	75	10	Yes	9	Yes	5	No
30	45	10	Yes	9	No	4	No
31	80	8	Yes	9	No	4	No
32	90	6	Yes	9	No	3	No
33	80	6	No	8	No	3	No
34	90	10	Yes	7	Yes	3	No
35	70	10	Yes	6	Yes	3	No
36	70	9	Yes	10	No	7	No
37	65	9	Yes	8	No	7	No
38	45	8	No	9	Yes	5	No
39	75	9	Yes	8	No	5	No
40	55	8	No	9	No	4	Yes
41	65	7	Yes	9	Yes	6	Yes
42	80	10	Yes	8	Yes	2	No
43	80	9	Yes	9	No	6	No
44	65	7	Yes	10	No	6	No
45	70	9	Yes	8	Yes	4	No
46	70	9	Yes	9	Yes	4	No
47	55	7	Yes	9	No	5	No

* Refers to answers to question 11 of final tests.

TABLE IV (*Continued*)

RESULTS OF PRELIMINARY AND FINAL TESTS

GROUP 2

PUPIL NO.	PRE EXAM.	1ST EXP. DEM.		2ND EXP. DEM.		3RD EXP. LAB.	
		SCORE	REACTION*	SCORE	REACTION*	SCORE	REACTION*
48	65	8	Yes	7	No	5	No
49	65	5	No	8	No	4	Yes
50	70	8	Yes	9	No	5	Yes
51	70	7	No	9	No	5	No
51	70	9	Yes	9	No	9	No
53	50	7	No	10	No	7	No
54	85	7	Yes	10	Yes	5	No
55	45	9	Yes	10	No	5	No
56	60	6	Yes	7	No	5	No
57	70	8	Yes	8	Yes	3	No
58	70	7	Yes	9	Yes	4	No
59	80	6	Yes	8	No	4	No
60	65	9	Yes	7	No	4	No
61	80	9	Yes	10	Yes	6	No
62	70	8	Yes	9	No	5	No
63	75	7	Yes	9	Yes	3	No
Mean	70.7	8.28	Yes 53	8.63	Yes 18	4.90	Yes 8
Median	72.97	8.96	No 10	9.12	No 44	5.36	No 55

* Refers to answers to question 11 of final tests.

of the scores of Group 1 by 1.42. In other words, the two measures of central tendency indicate in the first experiment that the demonstration method is in some degree more efficient in accomplishing results which the test measured.

In the second experiment, Group 1 worked under the laboratory method and Group 2, the slightly weaker group, worked under the demonstration method. The mean of the scores of Group 2 is greater than the mean of the scores of Group 1 by .56. The median of the scores of Group 2 is greater than the median of the scores of Group 1 by .57. In other words the two measures of central tendency indicate in the second experiment that the demonstration method is in some degree more efficient in accomplishing the results which the test measured.

In the third experiment, the groups were reversed: Group 1 worked under the demonstration method and Group 2 worked under the laboratory method. In this case, the mean of the scores of Group 1 is greater than the mean of the scores of Group 2 by .73. The median of the scores of Group 1 is greater

than the median of the scores of Group 2 by .78. Once more there is an indication that in some degree the demonstration method is more efficient in accomplishing the results which the test measured.

TABLE V

DISTRIBUTION OF SCORES IN FINAL TESTS FOR IMMEDIATE ESTABLISHMENT OF REALIZATIONS

GROUP 1		GROUP 2	
1ST EXPERIMENT (LAB. METHOD)		1ST EXPERIMENT (DEM. METHOD)	
SCORE	FREQUENCY	SCORE	FREQUENCY
10	1	10	14
9	8	9	17
8	10	8	12
7	12	7	13
6	4	6	5
5	6	5	2
4	4	4	0
3	4	3	0
	49		63
Mean	6.69	Mean	8.28
Median	7.54	Median	8.96
Difference in Means			1.59
Difference in Medians			1.42

2ND EXPERIMENT (LAB. METHOD)		2ND EXPERIMENT (DEM. METHOD)	
SCORE	FREQUENCY	SCORE	FREQUENCY
10	7	10	12
9	10	9	23
8	18	8	20
7	9	7	7
6	2	6	1
5	3	5	0
	49		63
Mean	8.04	Mean	8.60
Median	8.58	Median	9.15
Difference in Means			0.56
Difference in Medians			0.57

3RD EXPERIMENT (DEM. METHOD)		3RD EXPERIMENT (LAB. METHOD)	
SCORE	FREQUENCY	SCORE	FREQUENCY
9	3	9	1
8	2	8	2
7	10	7	6
6	11	6	11
5	11	5	18
4	8	4	14
3	3	3	8
2	0	2	3
1	1	1	0
	49		63
Mean	5.63	Mean	4.90
Medians	6.14	Medians	5.36
Difference in Means	0.73		
Difference in Medians	0.78		

TABLE VI

DISTRIBUTION OF ANSWERS TO QUESTION 11 OF THE FINAL TESTS

1ST EXPERIMENT		2ND EXPERIMENT	
DEM. METHOD	LAB. METHOD	DEM. METHOD	LAB. METHOD
Yes.....53	Yes.....25	Yes.....18	Yes..... 4
No.....10	No.....24	No.....45	No..... 45

3RD EXPERIMENT	
DEM. METHOD	LAB. METHOD
Yes..... 7	Yes..... 8
No.....42	No.....55

Table VI shows that in all three instances proportionately more pupils thought that they understood the experiments better when the experiments were demonstrated than when they were submitted to laboratory procedure. Question 11 reads, "Do you feel that you thoroughly understand this experiment?" The tabulation reveals that in the first experiment about 84 per cent of the pupils thought that they understood the experiment when the demonstration method was employed, and about 50 per cent of the pupils thought that they understood the experiment when the laboratory method was applied. In the second experiment, about 29 per cent thought that they understood the experiment when the demonstration method was used, and only 8 per cent of the pupils thought that they understood the

experiment when the laboratory method was used. In the third experiment, 14 per cent thought that they understood under the demonstration method and 13 per cent under the laboratory method. Table VI also shows that the second and third experiments presented considerable difficulty to the pupils.

The evidence in Table VI is of course entirely subjective: it can be used as an index in this investigation only in so far as a strong feeling of certainty about the understanding of the experiment is an indication of the presence in the mind of the pupil of the realizations pertinent to the experiment. Whatever valid evidence may be found in the table points to the greater efficacy of the demonstration method in establishing such realizations.

The results of tests reported thus far refer to relative efficacy in establishing realizations. Below will be found the results of tests given eight months after the initial tests for the purpose of examining for permanency of the realizations established. It should be recalled at this point that the tests, those found on pages 73, 74, 75, which were given in March were given again in November with the assumption that, if the realizations were still present in the minds of the pupils, they would be able to answer the questions and that if the realizations had faded from consciousness the answers would suffer proportionately.

Tables VII and VIII represent the individual scores made by each pupil in the Otis Tests and in the final tests given in November. Table IX shows the distribution of scores made in the November tests.

Table IX, page 86, allows comparison between the relative permanency of realizations as established in Group 1 and in Group 2 under the effect of the demonstration method and under the effect of the laboratory method. In two of the three instances both the arithmetic mean and the median of scores give the advantage to the demonstration method. The advantage, however, in all three instances as measured by the difference in scores is only very slight.

In the first experiment, it will be recalled, Group 1 worked under the laboratory method and Group 2, the slightly weaker

TABLE VII

RESULTS OF OTIS GROUP TESTS AND OF FINAL TESTS FOR PERMANENCY OF REALIZATIONS

GROUP 1

PUPIL NO.	OTIS EXAM.	1ST EXP. LAB.		2ND EXP. LAB.		3RD EXP. DEM.	
		SCORE	REACTION*	SCORE	REACTION*	SCORE	REACTION*
1	101	9	Yes	6	No	5	No
2	176	8	Yes	10	Yes	7	No
3	127	10	Yes	9	Yes	6	Yes
4	137	10	Yes	7	Yes	6	No
5	147	10	No	8	No	10	No
6	140	8	Yes	6	No	3	No
7	160	6	No	9	No	6	No
8	133	10	Yes	7	Yes	6	Yes
9	179	6	Yes	9	Yes	5	No
10	136	5	Yes	7	No	4	No
11	147	7	Yes	8	No	6	No
12	147	4	Yes	6	No	4	No
13	131	7	No	5	No	5	No
14	162	7	Yes	5	No	3	No
15	154	6		5		7	
16	156	7	No	9	No	7	No
17	123	7	No	10	No	6	No
18	86	7	Yes	6	No	3	Yes
19	97	7	No	5	No	0	No
20	144	7	Yes	8	Yes	7	No
21	188	10	No	9	No	9	No
22	132	7	Yes	6	Yes	6	No
23	136	10	Yes	8	Yes	5	No
24	131	9	No	6	No	4	No
25	172	9	Yes	9		3	No
26	139	4	No	6	No	4	No
27	152	8	Yes	6	No	6	No
28	109	6	No	6	No	2	No
29	170	8	No	9	No	6	No
30	112	6	Yes	3	No	4	No
31	155	9	Yes	9	Yes	5	No
32	142	9	No	8	No	5	No
33	187	10	Yes	9	No	5	No
34	204	10	Yes	9	Yes	8	No
35	166	5	No	8	No	6	No
36	148	10	Yes	7	No	5	No
37	130	7	Yes	5	No	2	No
38	141	9	Yes	8	No	2	No
39	143	4		9	No	4	
40	125	9	Yes	8	Yes	5	No
41	189	10	No	8	Yes	3	No
42	125	5	No	7	No	7	No
43	98	7	No	7	No	4	No
44	169	9	Yes	7	No	10	Yes
45	144	7	No	9	No	6	No
Mean	144.2	7.66	Yes 26	7.355	Yes 12	5.155	Yes 4
Median	142.5	7.96	No 17	8.06	No 31	5.61	No 39

* Refers to answers to question 11 of final test.

TABLE VIII

RESULTS OF OTIS GROUP TESTS AND OF FINAL TESTS FOR PERMANENCY OF REALIZATIONS

GROUP 2

PUPIL NO.	OTIS EXAM.	1ST EXP. DEM.		2ND EXP. DEM.		3RD EXP. LAB.	
		SCORE	REACTION*	SCORE	REACTION*	SCORE	REACTION*
1	175	8	No	7	No	6	No
2	141	8	Yes	8	No	5	No
3	166	9	Yes	8	No	4	No
4	162	4	Yes	9	No	3	No
5	131	9	Yes	8	Yes	6	No
6	124	7	Yes	8	No	3	No
7	144	9	No	6	Yes	7	No
8	133	8	Yes	7	Yes	5	No
9	144	9	Yes	7	Yes	6	Yes
10	161	9	Yes	8	No	7	No
11	162	7	No	7	Yes	3	No
12	141	9	Yes	9	Yes	6	Yes
13	162	6	Yes	5	Yes	3	No
14	169	8	Yes	8	No	10	Yes
15	179	9	No	10	No	8	No
16	131	10	Yes	8	No	7	No
17	121	5	Yes	6	No	4	No
18	132	7	Yes	8	No	5	Yes
19	101	5	Yes	6	Yes	2	No
20	153	7	Yes	8	No	4	No
21	132	10	Yes	6	No	6	No
22	112	7	Yes	10	No	7	Yes
23	158	8	Yes	5	No	7	No
24	139	4	Yes	7	Yes	5	No
25	141	9	Yes	4	No	4	No
26	135	9	Yes	8	No	6	No
27	158	4	No	7	No	5	No
28	101	7	Yes	5	No	6	No
29	188	9	Yes	7	No	6	Yes
30	132	6	No	6	No	4	No
31	152	8	Yes	7	Yes	4	No
32	156	6	Yes	6	No	6	Yes
33	135	7	No	5	No	5	No
34	144	9	Yes	8	No	5	No
35	121	5		3	No	4	No
36	130	8	Yes	5	No	6	No
37	173	6	Yes	6	Yes	7	No
38	132	10	Yes	9	No	5	No
39	178	9	Yes	8	No	6	No
40	143	10	No	7	No	5	No
41	162	9	Yes	7	No	5	No
42	131	10	Yes	5	No	5	No
43	124	9	No	9	Yes	6	No
44	180	7	No	4	No	3	No
45	136	9	Yes	5	No	3	No
46	124	9	Yes	4	Yes	5	Yes
47	170	7	No	5	No	5	No

* Refers to answers to question 11 of final tests.

TABLE VIII (*Continued*)

RESULTS OF OTIS GROUP TESTS AND OF FINAL TESTS FOR PERMANENCY OF REALIZATIONS

GROUP 2

PUPIL NO.	OTIS EXAM.	1ST EXP. DEM.		2ND EXP. DEM.		3RD EXP. LAB.	
		SCORE	REACTION*	SCORE	REACTION*	SCORE	REACTION*
48	176	8	Yes	6	Yes	5	No
49	118	5	No	8	No	3	No
50	155	7	No	9	No	4	No
51	123	9	Yes	10	Yes	4	No
52	110	7	Yes	5	No	5	No
53	118	8	No	7	No	7	No
54	87	5	Yes	8	Yes	4	Yes
55	152	9	Yes	8	No	4	No
56	134	9	Yes	3	No	4	No
57	144	8	Yes	7	Yes	8	Yes
Mean	142.7	7.70	Yes 42	6.84	Yes 17	5.14	Yes 10
Median	139.6	8.55	No 14	7.54	No 40	5.56	No 47

* Refers to answers to question 11 of final tests.

group, worked under the demonstration method. The mean of the scores of Group 2 is greater than the mean of the scores of Group 1 by .04. The median of scores of Group 2 is greater than the median of scores of Group 1 by .59. In the first experiment, therefore, the two measures of central tendency indicate that the demonstration method is in some degree (however slight) more efficient in assuring permanency of realizations once established.

In the second experiment, Group 1 worked under the laboratory method and Group 2, the slightly weaker group, worked under the demonstration method. The mean of the scores of Group 1 is greater than the mean of the scores of Group 2 by .51. The median of the scores of Group 1 is greater than the median of the scores of Group 2 by .52. In other words the two measures of central tendency indicate in the second experiment that the laboratory method is in some degree more efficient in assuring permanency of realizations. This is the only test throughout the whole investigation which has pointed toward the laboratory method as the more efficient method in accomplishing results which the tests measured.

In the third experiment, the groups were reversed: Group 1 worked under the demonstration method and Group 2 worked under the laboratory method. In this case the mean of the scores of Group 1 is greater than the mean of the scores of Group 2 by .015. The median of the scores of Group 1 is greater than the median of the scores of Group 2 by .05. There is here again just a slight indication that in some degree the demonstration method is more efficient in assuring permanency of realizations.

TABLE IX

DISTRIBUTION OF SCORES IN FINAL TESTS FOR PERMANENCY OF REALIZATIONS

GROUP 1		GROUP 2	
1ST EXPERIMENT (LAB. METHOD)		1ST EXPERIMENT (DEM. METHOD)	
SCORE	FREQUENCY	SCORE	FREQUENCY
10	10	10	5
9	8	9	19
8	4	8	10
7	12	7	11
6	5	6	4
5	3	5	5
4	3	4	3
	45		57
Median	7.96	Median	8.55
Mean	7.66	Mean	7.70
Difference in Means	.04		
Difference in Medians	.59		
2ND EXPERIMENT (LAB. METHOD)		2ND EXPERIMENT (DEM. METHOD)	
SCORE	FREQUENCY	SCORE	FREQUENCY
10	2	10	3
9	12	9	5
8	9	8	15
7	7	7	12
6	9	6	8
5	5	5	9
4	0	4	3
3	1	3	2
	45		57
Median	8.06	Median	7.54
Mean	7.35	Mean	6.84
Difference in Means	0.51		
Difference in Medians	0.52		

3RD EXPERIMENT (DEM. METHOD)		3RD EXPERIMENT (LAB. METHOD)	
SCORE	FREQUENCY	SCORE	FREQUENCY
10	2	10	1
9	1	9	0
8	1	8	2
7	5	7	7
6	11	6	12
5	9	5	15
4	7	4	12
3	5	3	3
2	3	2	1
0	1		
	45		57
Median	5.61	Median	5.56
Mean	5.155	Mean	5.14

Difference in Means.....0.015
Difference in Medians.....0.05

TABLE X

DISTRIBUTION OF ANSWERS TO QUESTION II OF THE FINAL TESTS FOR PERMANENCY OF REALIZATIONS

1ST EXPERIMENT		2ND EXPERIMENT	
DEM. METHOD	LAB. METHOD	DEM. METHOD	LAB. METHOD
Yes.....42	Yes.....26	Yes.....17	Yes.....12
No.....14	No.....17	No.....40	No.....31

3RD EXPERIMENT	
DEM. METHOD	LAB. METHOD
Yes..... 4	Yes.....10
No.....39	No.....47

Table X shows that in two of the three instances proportionately more pupils thought that they understood the experiment better, after a period of eight months, when the experiments were demonstrated than when they were submitted to laboratory procedure. Question 11 reads, "Do you feel that you thoroughly understand this experiment?" The tabulation reveals that in the first experiment about 75 per cent of the pupils thought that they understood the experiment when the demonstration method was employed, and about 60 per cent of the pupils thought that they understood the experiment after the laboratory method had been used in establishing the realizations. In the second experiment, about 29 per cent thought that they understood the experiment when the demonstration method was used, and 27 per cent of the pupils thought that they understood the experiment when the laboratory method

was used. In the third experiment proportionately more pupils, 17 per cent to 9 per cent, thought that they understood the experiment when performed in the laboratory method.

The evidence in Table X, like the evidence in Table VI, is entirely subjective: it can be used as an index in this investigation only in so far as a strong feeling of certainty about the understanding of an experiment is an indication of the presence in the mind of the pupil of the realizations pertinent to the experiment. Whatever valid evidence may be found in the table points to the fact that there is very little difference in the relative efficacy of the two methods in providing for permanency of realizations once established.

In conclusion, it may be said that this investigation, as well as five or six others mentioned above, suggests the probability of a fact not commonly recognized. The developmental-demonstration method is more efficient in establishing realizations in the minds of pupils than is the laboratory method. In every possible instance, even when the weaker group used the demonstration method, the demonstration method produced the better results in establishing realizations. As for the relative permanency of realizations established by the two different methods, the evidence is not so definite. The results of one experiment point to the laboratory method as the more efficient: the results of the other two experiments point to the demonstration method as the more efficient in providing for permanent realizations. The slight difference in means and medians in all three tests measuring permanency indicates at least no marked advantage in favor of either method in regard to permanency of established realizations.

In such a fashion must every factor in establishing forms of control be treated. Only experimentation of the kind exemplified can ultimately determine the adequacy of the elements listed under each complex of Chapter 5, the method best adapted to the fixing of each element itself, the most satisfactory application of each complex, and all of the many problems that arise in making education control conduct. The writer wishes to repeat once more his emphasis of the intimate relationship between the analysis of Chapter 5 and experimentation as exemplified in Chapter VI.

APPENDIX

Instructions for Experiment 1

Introductory Questions (to be answered at home):

1. Of what use is a pendulum to a clock?
2. What is a seconds pendulum?
3. What is meant by the frequency of a pendulum?
4. What is meant by a single vibration?
5. What is meant by the period of vibration?
6. How would you determine the period of vibration of a pendulum?

Object of experiment: To observe the effect on the number of vibrations of a pendulum in one minute of (a) change of weight, (b) change in length of arc, (c) change in length of string.

Apparatus: A wood and a metal ball each about 1 inch in diameter and having a light cord about 125 cm. attached; a special pendulum support; metronome or laboratory clock with telegraph sounder.

Directions:

There will be furnished a metal and a wooden ball of the same size, attached to a light cord over a meter long. As the suspending cord is very light, we neglect its weight and consider the length of the pendulum as the distance from the lower edge of the support to the center of the suspended ball or bob.

For the first test, adjust the length of the pendulum with the wooden ball to 100 cm. Count and record the number of vibrations made in one minute swinging through a small arc. Replace with a metal pendulum and find how many vibrations that makes in one minute swinging through the same arc. Comparing these numbers will show whether or not the material of the pendulum affects the period of vibration.

Now swing the metal bob through an arc twice as great as before, counting the number of vibrations per minute. Make the length of the pendulum 50 cm. and find the number of vibrations per minute. Repeat with lengths of 36cm. and 25 cm.

Record all observation in tabular form near the top of the left-hand page.

Observations:

Vibrations per minute, bob wood, length 100 cm., arc small.....
Vibrations per minute, bob metal, length 100 cm., arc small.....
Vibrations per minute, bob metal, length 50 cm., arc small.....
Vibrations per minute, bob metal, length 36 cm., arc small.....
Vibrations per minute, bob metal, length 25 cm., arc small.....

Instructions for Experiment 2

Introductory Questions (to be answered at home):

1. What is meant by a fulcrum?
2. What is meant by the center of gravity?
3. What is meant by a moment of force?
4. How is a moment of force computed?
5. A lever 10 ft. long has the fulcrum at its center. A 10-lb. weight is attached 3 ft. from the fulcrum on one side; how many pounds must be attached at the other end in order to balance the lever?
6. A lever 10 ft. long has the fulcrum at its center. A 20-lb. weight is attached 4 ft. from the fulcrum on one side; how many pounds must be attached 3 ft. from the fulcrum on the other end?

Object of Experiment: To find the amount of force acting at the center of gravity of a body.

Apparatus: Half meter stick loaded at one end; fulcrum; 200-gram weight with loop of cord attached; platform balance; metric weights.

Directions:

The body will be a half meter stick loaded at one end. This is first to be balanced over a fulcrum in order to find the center of gravity. Then a 200-gram weight will be hung about 10 cm. from the free end of the bar and the bar again balanced.

By measuring the distance of the 200-gram weight from the fulcrum and multiplying this distance by the weight (200 g.) the moment of the 200-gram weight is obtained. This moment equals the moment of the force at the center of gravity about the fulcrum. Then the force at the center of gravity is calculated. Ask instructor for directions.

A second trial should be made with the weight at some other point on the stick, as 20 cm. from the end.

Finally the loaded stick is weighed.

All observations as soon as made should be recorded in tabular form near the top of the left-hand page.

Observations:

	1.	2.
Position of center of gravity of loaded stick.....		
Position of 200-gram weight.....		
Position of fulcrum for equilibrium.....		
Weight of loaded stick.....		

Instructions for Experiment 3

Introductory Questions (to be answered at home):

1. How is a force measured mechanically?
2. How is a force represented graphically?
3. What is meant by the resultant of two or more forces?
4. To what is the resultant of two parallel forces equal? Describe an experiment to prove your answer.
5. What is meant by equilibrium? components of a force?
6. How do we compute the resultant of two parallel forces acting in opposite directions?
7. How do we compute the resultant of two forces acting at an angle? Describe an experiment to prove your answer.

Object of Experiment: To find the relation between three forces acting on a body at a point, in order that they may be in equilibrium.

Apparatus: 3 spring balances (2000 g.); fish line or other light strong cord; 3 clamps; 30 cm. ruler.

Directions:

Connect the three spring balances by three cords that meet at a point A. Fasten these balances in place by clamping the attached wires. Pull on the third balance until the pointer on one of the balances is near the end of the scale and then clamp the third balance in place.

Place the right-hand page of the note-book under the cords with the center of the page under the point A. Mark two points directly beneath each cord. Remove the book and through each pair of points draw a line which represents in direction the force. Note and record on the diagram, the reading of each balance, calling the balances B, C, D. Measure from A along each line a distance to represent the magnitude of the forces, using a scale of 1 cm. to 250 grams. Place at the end of each line an arrowhead to show the direction of the force.

Select one force as the equilibrant and lay off from A the resultant equal and opposite to the equilibrant. On the two lines representing the components, erect a parallelogram and draw the diagonal from A. Determine the magnitude of the force which this diagonal would represent. Compare it with the resultant which you laid off and drew.

Mark on the drawing the lengths of the lines and the readings of the balances. No table of results is necessary on the left-hand page, but write a simple description of the method of the experiment.

Calculated Results:

Magnitude of resultant.....g.
Magnitude represented by diagonal.....g.

Question Sheet for Experiment 1

To the pupil:

You will find below the directions of an experiment which was performed in your last semester's course in physics. Read the directions carefully, try to remember the details of the experiment, and then answer the questions printed at the end of the directions Your answers should be written in pencil on this sheet and in the spaces provided at the end of each question. Be sure to sign your name.

Directions

There will be furnished a metal and a wooden ball of the same size, attached to a light cord more than a meter long. Because the suspending cord is very light, neglect its weight and consider the length of the pendulum as the distance from the lower edge of the support to the center of the suspended ball or bob.

For the first test, adjust the length of the pendulum with the wooden ball to 100 cm. Count and record the number of vibrations made in one minute swinging through a small arc. Replace with a metal pendulum and find how many vibrations it makes in one minute swinging through the same arc. Comparing these numbers will show whether or not the material of the pendulum affects the period of vibration.

Now swing the metal bob through an arc twice as great as before, counting the number of vibrations per minute. Make the length of the pendulum 50 cm. and find the number of vibrations per minute. Repeat with lengths of 36 cm. and 25 cm.

Record all observations in tabular form near the top of the left-hand page.

Questions

1. Does the weight of the bob make a difference in the time of vibration?.....
2. Does the kind of substance make a difference in the time of vibration?.....
3. Does the length of string make a difference in the time of vibration?.....
4. Does the size of the arc make a difference in the time of vibration?.....
5. Did we consider in any way the weight of the thread?.....
6. If we wished fewer vibrations per minute should we lengthen or shorten the string?.....
7. Does it take a pendulum longer to swing through a long arc than through a small one?.....

8. If you wished the pendulum of a clock to make fewer vibrations per minute, what should you do to it?.....
9. Upon what factor does the rate of vibration of a pendulum depend? .....
10. What was the object of the experiment?.....
11. Do you feel that you very vividly remember the details of the experiment?.....

Name of pupil.....

Question Sheet for Experiment 2

To the pupil:

You will find below the directions of an experiment which was performed in your last semester's course in physics. Read the directions carefully, try to remember the details of the experiment, and then answer the questions printed at the end of the directions. Your answers should be written in pencil on this sheet and in the spaces provided at the end of each question. Be sure to sign your name.

Directions

The body will be a half meter stick loaded at one end. This is first to be balanced over a fulcrum in order to find the center of gravity. Then a 200-gram weight will be hung about 10 cm. from the free end of the bar and the bar again balanced.

By measuring the distance of the 200-gram weight from the fulcrum and multiplying this distance by the weight (200 g.), the moment of the 200-gram weight is obtained. This moment equals the moment of the force at the center of gravity about the fulcrum. Then the force at the center of gravity is calculated.

A second trial should be made with the weight at some other point of the stick, as 20 cm. from the end.

Finally the loaded stick is weighed.

Questions

1. How was the meter stick loaded?.....
2. Must the lever used in this experiment be made of wood?.....
3. Is it necessary to know the weight of the loaded meter stick?.....
4. Is it necessary to know the weight of the meter stick without the load?.....
5. Is it necessary to know at just what point the fulcrum is placed?... ... ...
6. What force acts at the center of gravity, the 200-gram weight or the weight of the loaded meter stick itself?.....
7. Would calculated results be different if the fulcrum were made of aluminum?.....

8. At what spot do we consider the weight of the loaded meter stick to be acting?.....
9. How was the center of gravity of the loaded stick located?.....
10. Does the center of gravity of the loaded meter stick change from one minute to the next?.....
11. Do you feel that you very vividly remember the details of the experiment?.....

Name of pupil.....

Question Sheet for Experiment 3

To the pupil:

You will find below the directions of an experiment which was performed in your last semester's course in physics. Read the directions carefully, try to remember the details of the experiment, and then answer the questions printed at the end of the directions. Your answers should be written in pencil on this sheet and in the spaces provided at the end of each question. Be sure to sign your name.

Directions

Connect the three spring balances by three cords that meet at a point A. Fasten these balances in place by clamping the attached wires. Pull the third balance until the pointer on one of the balances is near the end of the scale and then clamp the third balance in place.

Place the right-hand page of the note-book under the cords with the center of the page under the point A. Mark two points directly beneath each cord. Remove the book and through each pair of points draw a line which represents in direction the force. Note and record on the diagram, the reading of each balance, calling the balance B, C, D. Measure from A along each line a distance to represent the magnitude of the force, using a scale of 1 cm. to 250 grams. Place at the end of each line an arrowhead to show the direction of the force.

Select one force as the equilibrant and lay off from A the resultant equal and opposite to the equilibrant. On the two lines representing the components, erect a parallelogram and draw the diagonal from A.** Compare it with the resultant which you laid off and drew.

Mark on the drawings the lengths of the lines and the readings of the balances.

** Determine the magnitude of the force which this diagonal would represent.

Questions

1. May any one of the forces in equilibrium be taken as the equilibrant?
.....

2. Should the resultant and the equilibrant be equal in magnitude? .....
3. How is the magnitude of the forces measured? (How found?)..... .....
4. How is the equilibrant measured? (How found?).....
5. How is the resultant determined? (How found?).....
6. Is it necessary to draw a parallelogram in order to determine the magnitude of the three forces?.....
7. Is it necessary to draw a parallelogram in order to determine the magnitude of the equilibrant?.....
8. Did the marking on the balances represent pounds, grams or cm.? .....
9. Must the forces in all three directions be equal in order to produce equilibrium?.....
10. Is it necessary to measure the length of the diagonal of the parallelogram at any time during the experiment?.....
11. Do you feel that you very vividly remember the details of the experiment?.....

Name of pupil.....

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